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RAPPORTS
ET
PROCÈS-VERBAUX DES RÉUNIONS

Volume 150

ICES/ICNAF REDFISH SYMPOSIUM

Also published as Special Publication No. 3 of
The International Commission for the
Northwest Atlantic Fisheries

En Commission chez
ANDR. FRED. HØST & FILS
COPENHAGUE

Kr. 75.00

Septembre, 1961

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Editor's Note

The value of an International Symposium can be judged only when the meeting documents have been published. It is essential, therefore, that the editing of contributions should be carried out as speedily as possible.

To meet this need for the Redfish Symposium, technical editing has been limited and major interpretational disagreements between Editor and author – and there have been some – were not entered into. They could only have led to delays whilst papers were rewritten. It would also be unwise at this stage of knowledge for anyone to be categorical about many aspects of redfish research. All necessary alterations, for clarity of meaning, have been made with the author's approval.

It is a pleasure to record my thanks to Miss *Rose Bedford* of the Fisheries Laboratory, Lowestoft, for her valuable help in preparing the manuscripts for publication and for her meticulous care in checking them.

G. C. Trout
5. 7. 1960.

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THE REDFISH OF THE NORTH ATLANTIC

Chairman's Report and Introductory Remarks

Chairman: Dr. J. LUNDBECK; Rapporteur: G. C. TROUT

The Redfish Symposium was held at Copenhagen in the Charlottenlund Slot, between 12. and 16. October 1959, under the joint sponsorship of ICNAF and ICES and the Chairmanship of Dr. J. Lundbeck.

The absence of the late Dr. Å. Vedel Tåning was felt deeply during the meetings and frequent reference was made in discussions on many topics to his pioneer work on this genus. Because of his early definition of the many problems and potentialities of the North Atlantic redfish populations, and, in particular, his wide ranging studies of their larval stages, it was fitting that the Symposium should be held at his laboratory.

During the Biarritz meetings on fisheries methodology in 1956, when differences in interpreting redfish otolith structures had persisted after a workshop meeting, it became evident that a meeting devoted solely to redfish problems was required. Furthermore, there was a general lack of information on many aspects of redfish biology and also a dissatisfaction with the nomenclature used on both sides of the Atlantic.

At the 1957 Annual Meeting of ICNAF, the Committee of Research and Statistics decided that a Redfish Symposium should be held, and, since many of the problems were common to the north-east and the north-west Atlantic, ICES was asked to co-sponsor the meetings. Furthermore it was decided that the Symposium should be held in Copenhagen immediately after the ICES meeting in order that more European redfish workers could attend.

The Symposium covered several topics largely concerned with taxonomy but these were considered necessary preliminaries to the solution of conservation problems, which required, for example the determination of the distribution and the boundaries of each of the several North Atlantic Redfish stocks. Clarification of one problem–namely whether the growth-rate of redfish was fast or slow – acquired a considerable urgency, when, in June 1959 the ICNAF Fishery Assessment Working Group was set up to investigate the state of the main fisheries and fish stocks in the north-western Atlantic, including the redfish, and to assess the effects of different conservation measures which might be applied to them.

The discussions on systematics and on age determination were therefore of the greatest importance and it was indeed fortunate that all participants to the Symposium were able to attend these, and other discussion group sessions. These were arranged as follows:–

	Discussion Leader
Systematics, morphometry	Dr. Giles Mead
Systematics, serology and natural marks	Dr. Carl Sindermann
Distribution, including hydrography	Dr. W. Templeman
Larval studies	Dr. H. Einarsson
Sex and maturity in relation to migration	Dr. J. Magnússon
Age and growth	Dir. G. Rollefsen

In connection with the discussions on Systematics, a demonstration of a number of redfish samples from many regions, including nearly related forms from the Pacific, proved of considerable value. Redfish otoliths and the methods of preparing and viewing them, were also demonstrated, prior to the Age and Growth session, and Mr. George Kelly enlivened the meeting with an excellent film of his tagging experiments in the Eastport, Maine, redfish population.

During the last session, on age determination, the Symposium reached a decision in favour of slow growth —though further work is still required to confirm this interpretation—but no firm agreement was reached in discussions on Systematics and stock identification. However, the discussions and the demonstration clarified the situation to some extent. Far more work must be done before a full understanding of the status of the various North Atlantic *Sebastes* populations is forthcoming. In the meanwhile, interpretation of the data is still controversial and readers should refer to the joint report of Drs. Giles Mead and Carl Sindermann.

Nevertheless, on morphological, serological, ecological, and behavioural grounds there seems good reason to separate the *Sebastes marinus* and *Sebastes mentella* of the Barents Sea as full species, although this is not evident from Kelly's treatment of morphometric data. On the other hand, the common North American redfish, often referred to as *Sebastes marinus,* or sometimes, and surely, since it is a "beaked" redfish, more logically, as the "American *mentella*", has been shown to produce larvae with caudal pigmentation. In this, it differs from *S. mentella* caught elsewhere.

Although Templeman and Sandeman's observations were restricted to late pre-extrusion larvae from the Hermitage Bay area of South Newfoundland, Flemish Cap, and from as far north as Hamilton Inlet Bank, off Labrador, Tåning's earlier field studies from the region of the Flemish Cap, can be taken as confirmation of caudal pigmentation occurring in the released, planktonic larvae. No such caudal pigmentation has, so far, been reported in planktonic larvae from the Barents Sea or Central North Atlantic, except in the larvae of the commercially unimportant *S. viviparus.*

Thus whilst *S. marinus* appears to possess relatively uniform characteristics, whether it comes from the Barents Sea or from the coast of Labrador, there appear to be major differences between the "American *mentella*" and the *S. mentella* from the Barents Sea and other regions. The main difference—larval pigmentation—would appear to be genetic and is thought to be sufficient to warrant a different name being given to the American *"mentella"*-like form. Whether this should be a specific or sub-specific name is for the results of further work to decide. Whether, too, the widely separated fisheries for *S. marinus* are dependent upon a central, largely pelagic and oceanic reservoir of this species, still requires confirmation and this problem will have to be settled before the redfish assessment studies can be completed. The facts presented by Sorokin and other Russian workers for the Barents Sea; by Magnússon for the Iceland/Greenland region; and those derived by Dietrich, Aurich and Kotthaus, from their important hydrographic approach to the study of larval distribution, would appear to be against this concept of one oceanic population. Again, more research is required before the position is clear.

Recommendations for future research are contained in the reports of the Chairmen of the Discussion Groups. They should be implemented by a co-ordinated research programme using serological and biochemical techniques particularly in the north-west and central regions of the Atlantic, in order to resolve the status and the interrelationships of the several redfish stocks and the relationship and origin of the "intermediates" reported and demonstrated by Dr. Kotthaus.

Results from larval studies showed a remarkable measure of agreement in the many papers tabled, so that an extension and intensification of the present work and methods should be adequate to fill in the gaps in the knowledge of larval distribution, origin and parentage.

Whilst these are perhaps the main issues, the more detailed reports and recommendations of the six Topic Chairmen point to many more problems still to be elucidated. Some of these would derive benefit from joint planning of research projects and shared research vessel effort, in order to make the most effective use of research time and resources.

Acknowledgments

At the conclusion of the meetings, Dr. Lundbeck expressed his gratitude to the Discussion Leaders for their contribution to the success of the Symposium, and asked that the thanks of the entire meeting should be conveyed to the staff of the Danish Institute for Fishery Research at the Charlottenlund Slot, whose constant attendance and help had made for the smooth running of all activities.

SECTION I
SYSTEMATICS AND NATURAL MARKS

Discussion Leaders: Dr. GILES W. MEAD and Dr. CARL J. SINDERMANN

Section A

Alverson, D. L., & Westrheim, S. J. "A review of the taxonomy and biology of the Pacific Ocean perch and its fishery".

Kelly, G. F., Barker, A. M., & Clarke, G. M. "Racial comparisons of redfish from the western North Atlantic and the Barents Sea".

Kotthaus, A. "Contributions to the race problem in redfish".

Kotthaus, A. "Preliminary remarks about redfish otoliths".

Phillips, J. B. "Problems in the identification of fishes, with a comparison between shallow-water and deep-water species of *Sebastodes* (Scorpaenidae)".

Templeman, W., & Pitt, T. K. "Vertebral numbers of redfish, *Sebastes marinus* L. in the north-west Atlantic, 1947–1954".

Travin, V. I. "A brief survey of Soviet investigations in redfish (*Sebastes* genus)".

Trout, G. C. "*Sebastes viviparus* (Krøyer) and the redfish problem".

Section B

O'Rourke, F. J. "An immunological and chromatographic study of *Sebastes marinus* L. and *Sebastes mentella* Travin".

Schaefer, H. "A biochemical contribution to the redfish problem".

Sindermann, C. J. "Parasitological tags for redfish of the western North Atlantic".

Sindermann, C. J. "Serological studies of redfish".

Templeman, W., & Squires, H. J. "Incidence and distribution of infestation by *Sphyrion lumpi* (Krøyer) on the redfish, *Sebastes marinus* L. of the western North Atlantic, 1949–1953".

Since the section devoted to a discussion of "natural marks" (serological, parasitological, and biochemical) and that devoted to the methods and results of systematics studies, are directed toward a common end, a joint report of the results of these two sections is submitted here.

The participants in this symposium have recognized the two parallel taxonomic aspects of the redfish problem. The first is the systematic nature of the population of North Atlantic *Sebastes* in an evolutionary sense and is concerned with ancestry, biological or reproductive isolation and gene flow, and speciation and variation in a rather comprehensive sense. The second aspect is a more pressing one of direct concern in fishery assessment and management: what population units, or stocks, can be delimited for management purposes, and whether such definition can be attempted in the immediate future. These two aspects are comparable, and the full answer to the problem in a systematics sense would provide complete answers to the questions asked by students of population dynamics and the fishery.

The several contributions to the symposium on morphological variation and the separation of populations by anatomical differences, although to some extent inconclusive, have helped to define the problem and to clarify our understanding of it. Dr. Krefft has provided a provocative hypothesis concerning the origin of the North Atlantic *Sebastes,* particularly the American forms known as *mentella*-type and the eastern Atlantic *marinus*-type, from two subspecies of the related and more primitive genus *Helicolenus (H. dactylopterus maderensis* and *H. d. dactylopterus* respectively) or their predecessors.

Similarly, in a discussion not presented to the symposium in written form, Mr. B. B. Parrish has provided notes on the criteria necessary to the assessment biologist in any consideration of "stocks". Similar remarks were presented in Mr. Gulland's contribution to this symposium. Since Mr. Parrish's comments will not appear elsewhere, we have included a part of them in this report, as follows:–

"Whereas the taxonomic status of 'groups' of fish is of major importance in the proper understanding of the evolution and genetics of the group, population studies are interested, principally, in identifying unit stocks or management units which can be treated as separate dynamic groups. Thus 'groups' of very different taxonomic status can, as dynamic groups, have the same significance in population management".

"The essential property of a unit stock, as a management unit, is that it is sufficiently self-contained biologically so that its abundance (number and weight) is determined by factors operating within its boundaries, which affect either recruitment, growth or mortality. A consequence of this is that any fishery management procedure will operate principally on the parameters of that defined group."

"The specific demands in the unit stock concept will, in fact, vary according to the type of management measure under consideration. For some types, e. g. control of age of first capture, the principal requirements are 'groups' of 'uniform' growth-rate and mortality, but for some others, the demand is for more 'complete' biological groups".

"In many instances there is wide biological variation within the boundaries of a single taxonomic group, and often there are major differences between the sexes in growth, maturation, etc. In population studies these differences may be of greater importance than differences between taxonomic groups. Further, it may sometimes be possible to treat two or more distinct taxonomic groups, having similar population parameters, together for assessment purposes".

"Essentially, the major task with *Sebastes* at present is to look for geographical boundaries between groups within its total distribution, for which, despite much variation, there is some evidence of uniformity about its population parameters." (End of quotations from Mr. Parrish.)

It has become apparent during this symposium that satisfactory answers can be provided for but few questions. It has become equally apparent that answers or at least close approximations must be had now. The conclusions which follow may represent the concensus of the participants in the systematics and natural marks discussions.

1. *Sebastes viviparus* is a species clearly distinct from its congeners in general form, structure of otolith, fin ray, vertebra and scale complement, colour, growth-rate, and perhaps other features. It is common in waters more shallow than those of the larger species but does occur throughout the depth range of the commercial populations. *S. viviparus* has been found from East Greenland and Iceland eastward to Great Britain, the Faroes, and the coast of Norway. There are indications that *S. viviparus* is more closely allied to the American *mentella*-type redfish than to the eastern Atlantic forms. Since it is easily recognizable and not important in the commercial landings, it need be of no further interest in population dynamics problems.

2. The commercial American fishery for redfish in the north-west Atlantic is based upon the *mentella*-type redfish which may constitute three stocks for assessment purposes. The first of these lives in waters comprising ICNAF Subareas 4 and 5, and Division 3 O and 3 P (the south-west Grand Banks and westward to the Gulf of Maine and including the Gulf of St. Lawrence). The second area is ICNAF Division 3 K, 3 L, and Subarea 2 (the northern Grand Banks, the Newfoundland shelf, and the coast of Labrador). These two groups intermingle in Division 3 N, the south-eastern Grand Banks, in which the situation is not yet clear. The third area is Division 3 M (Flemish Cap).

The restriction of reproduction in the north, and the restrictive influence which the Gulf Stream waters will have on the eastward drift of viable larvae in the south, together with suspected larval drift patterns in the area, contribute to the isolation of these populations. There may be local variation within these populations, for the studies of parasite infection reported by Dr. Templeman and Dr. Sindermann, and the analysis of vertebral counts reported by Dr. Templeman, show that these fishes are chiefly non-migratory. Further suggestions of slight geographical variations were demonstrated in Mr. Kelly's morphometric analysis. The growth-rates reported by Mr. Kelly and Mr. Sandeman were similar, the sexes being considered separately. The occasional *marinus*-type individuals, and the local inshore populations of peculiar behaviour such as the Eastport, Maine, population discussed by Mr. Kelly, should be excluded for assessment purposes.

3. From the morphometric data available, the known growth-rates, behavioural patterns, the structure of the otolith, and lastly the biochemical distinctions discussed by Professor O'Rourke, it seems apparent that Barents Sea *mentella*-type and *marinus*-type *Sebastes* must be considered distinct for population analyses, whatever the systematic status and relationship of each may be.

4. In the absences of discrete characters for the separation of *marinus*-type from *mentella*-type redfish in the East Greenland/Iceland/Faroes area, we concur with the conclusion reached by Dr. Kotthaus: that the separation of types in this area is at the present time difficult and in many instances impossible. The possible influence of length of pelagic life in this area, food preferences, conditions at time of spawning etc., on morphometry was discussed, and the concensus was that much more information of the first few years of life would be required before a meaningful taxonomic

analysis would be possible. The opinion that the intermediate types abundantly represented in Dr. Kotthaus's material could be allocated to one type or another was expressed. In the absence of objective criteria for a more complete separation, no conclusion could be reached. Biochemical and serological methods could appropriately be applied to a study of these intermediates. A similar approach could be used to establish the distinctiveness, or the relationships, of the "giant" fish occasionally found in most areas.

5. Biochemical and serological characteristics offer definite promise of providing information of value to the study of redfish groups.

6. Opinion was divided on the usefulness of otolith form as an indicator of environmental conditions, races, subspecies or species. It is obvious that in certain areas otolith type is a species or type characteristic, but it is equally obvious that a great deal of geographical variation exists.

Several suggestions for future work seem in order:—

(a) Available data on the American *mentella*-type commercial redfish stocks, as tentatively defined above, should be reviewed by biologists in the ICNAF area with respect to the parameters essential to assessment and management, prior to the further application of an assessment programme.

(b) In view of the potential value of biochemical and serological methods for studying systematics and populations of fish, these methods should be encouraged in the analyses of redfish populations of the North Atlantic. There are several ways in which they could be assisted by ICES and ICNAF.

(i) By encouraging senior university staff biochemists and serologists with grants in aid and summer employment at fisheries laboratories;

(ii) by arranging for the preparation and publication of a handbook describing various methods used;

(iii) by encouraging government employment of serologists and biochemists in fisheries laboratories;

(iv) by arranging a world meeting, possibly in conjunction with the forthcoming FAO conference on fish physiology, of those working with serological and biochemical approaches to fish taxonomy.

(v) It is further recommended that certain biochemical determinations be accomplished at sea on freshly-caught individuals.

(c) Whereas the eastern, and the western, *mentella*-type and *marinus*-type redfish can be distinguished visually in the Barents Sea and the more northern American waters, less progress has been made toward the separation of types in more central areas. A study of the changing characteristics of these types, starting with the more northern areas, should be attempted in an effort to interpret the nature of the intermediate types prominent in data such as that presented by Dr. Kotthaus.

(d) One recommendation proposed by Dr. H. Einarsson and included in his report on the "larval studies" discussion is of particular significance to the taxonomic question. The further study of larval characteristics, particularly the pre-extrusion larvae in the ICES area and the planktonic larvae in the waters south and west of Greenland, is essential.

(e) The morphological data presented by Dr. Kotthaus and Mr. Kelly do not separate adequately the redfish types found between East Greenland, Iceland, and the Faroes. Similarly, an adequate explanation of larval peculiarities such as the differing length-frequency modes reported by Mr. Vagn Hansen and Mr. K. P. Andersen may involve taxonomic as well as reproductive factors. Reproduction, pelagic life and its duration, food preferences and growth, etc., have a direct bearing on taxonomy; the accumulation of information bearing on these questions is vitally needed.

(f) Attempts to provide objective criteria, including colour and other field characters, for the separation of *mentella*- and *marinus*-type redfish should continue.

(g) The possible effect of environment on body form, the behaviour of larvae, and many other questions of importance in taxonomy and redfish biology in general was reflected in all discussions. Many of these questions could be resolved if redfish and their young could be kept in controlled aquaria. The occurrence of redfish in shallow water, such as the Eastport, Maine, population studied by Mr. Kelly, provides a source of material for such experimental work, and it is strongly urged that such studies be undertaken whenever and wherever the opportunity may arise.

A. I

A Review of the Taxonomy and Biology of the Pacific Ocean Perch and its Fishery

By

DAYTON L. ALVERSON[1]) and SIGURD J. WESTRHEIM[2])

Introduction

The development of a fishery for Pacific ocean perch, *Sebastodes alutus,* along the west coast of the United States and Canada has stimulated interest in the biological and taxonomic relationships which may exist between this species and the Atlantic species of redfish, *Sebastes marinus.* To aid fisheries workers in current or future comparative studies of the differences between the commercially-exploited scorpaenids of the Atlantic and the Pacific Oceans, the authors have reviewed and abstracted the more important publications relating to the biology and the taxonomy of the Pacific ocean perch and its fishery.

Systematics

The family Scorpaenidae is represented on the west coast of North America by three genera. Two of these, *Sebastolobus* and *Sebastodes,* have a range extending from Baja California to the Bering Sea. The other, *Scorpaena,* is represented by one species, the sculpin rockfish, *S. guttata,* which inhabits the waters from Baja California north to Point Arguello, California.

A key to the genera of North American scorpaenids taken from Phillips (1957) follows.

A Key to Genera of Scorpaenidae

1-a. Dosal fin spines, 15 or 16; rarely 17; dorsal fin rays, 8–10; vertebrae, 29 ...... *Sebastolobus.*

1-b. Dorsal fin spines, 13; rarely 11, 12, or 14; dorsal fin rays, 11–18; vertebrae, 26–27 ... . *Sebastodes.*

1-c. Dorsal fin spines, 12; dorsal fin rays, 9 or 10; rarely 8; vertebrae, 24 .... *Scorpaena.*

Sebastolobus is represented by two species, *alascanus* and *altivelis,* which are called "idiots" by fishermen and "thornheads" by taxonomists. These species are common along the continental slope at depths ranging from 80 to 500 fathoms; however, the bathymetric range is probably more extensive. Phillips (op.cit.) reports a depth range from 50 to 800 fathoms.

The genus *Sebastodes** is one of the most complex and confused groups confronting west coast marine taxonomists. The work of Phillips on the rockfishes of California represents an excellent contribution and effort towards unravelling the existing taxonomic chaos. Other recent works concerning the systematics of *Sebastodes* include papers by Sunde and Lindsey (1958), Wilimovsky (1958), and Alverson and Welander (1952). All of the studies, however, consider restricted portions of the generic range, and no comprehensive review of the rockfishes along the west coast of North America has been attempted since the work of Jordan and Evermann (1898).

The number of described species of *Sebastodes* within the literature far exceeds the number that local taxonomists accept as valid. Contemporary estimates as to the number of species range between 53 and 58, with authors qualifying the stated number with "about" or "approximately". In recent years reviews of the rockfish group have reduced some previously accepted species to synonym or subspecies status, and hybridization has been noted. Phillips (1957) reports eight synonyms and three tentative hybrid forms.

The greatest number of species types along the Pacific coast of North America occurs at the southern end of the generic range. Forty-nine *Sebastodes* are reported off California by Phillips (op. cit.). Alverson and Welander (1952) and Welander and Alverson (1954) record 29 species for Washington and adjacent waters. Sunde and Lindsey (1958) report 23 species off British Columbia. Wilimovsky (1958) records 20 species occurring off Alaska. Only one of the 20 species listed for Alaska, *S. polyspinus,* is restricted to the Alaska portion of the generic range, while 17 of the species occur off British Columbia and the States of Washington, Oregon, and California. One species, *S. entomelus,* has been reported from Alaska and from California, but not from off Washington and British Columbia. Of the 23 species known off British Columbia, all have been reported taken off the State of

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[1] Chief, North Pacific Fisheries Exploration and Gear Research, U.S. Fish and Wildlife Service, Bureau of Commercial Fisheries, Seattle, Washington.

[2] Director of Research, Oregon Fish Commission, Clackamas, Oregon.

* Throughout the text the authors have used genus name *Sebastodes,* which is in common usage by west coast taxonomists. We, however, are of the opinion that the inter-generic differences between *Sebastes* and *Sebastodes* do not warrant this separation and suggest following Matsubara (1943) in use of *Sebastes* for the Pacific species of *Sebastodes.*

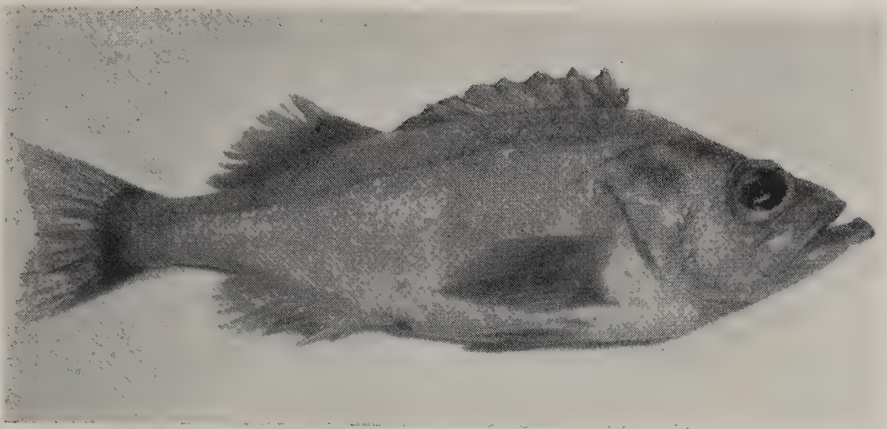

Figure 1. Pacific ocean perch (*Sebastodes alutus*).

Washington. All but two species, *S. emphaeus* and *S. ciliatus,* recorded off Washington are known to exist off the California coast.

The species within the *Sebastodes* group vary considerably in osteology, morphology, and colour patterns. Differences in skull shape and the presence or the absence of cranial spines are chief characters used for identification. The interorbital space may be strongly convex with vestigial or no obvious spines on the supraorbital ridges, such as in *S. melanops* and *S. flavidus,* or greatly concave with strongly developed ridges and spines as in *S. nigrocinctus.* Between these extremes lie intermediate forms which are described as having moderately or slightly convex and sometimes flat interorbital areas. Morphometric and meristic data for many of the *Sebastodes* group of North America are given by Phillips (1957).

Colour patterns vary considerably between species, and therefore the patterns in fresh specimens can be used to aid identification. Rockfish with shades of brown, black, yellow, green, orange, and pink are common in the shallower waters (<100 fathoms) along the continental shelf. In the deeper waters (>100 fathoms), rockfish of shades of red predominate. The species of *Sebastodes* inhabiting the shallower waters are, for the most part, larger and rotund in contrast to smaller, elongate ones found along the continental slope. Body depth varies considerably between species and may range from 4:1 in the standard length (*S. nigrocinctus*) to 2·5:1 (*S. jordani*).

Many of the closely related species show only slight differences, which makes field identification difficult. Keys used at present for species identification have been provided by Sunde and Lindsey (1958), Jordan and Evermann (1898), Schultz (1936), Clemens and Wilby (1949), Alverson and Welander (1952), Phillips (1957), and Wilimovsky (1958). A field key for identification of *S. alutus* only has also been published by Westrheim (1958).

Sebastodes alutus was originally described from a 6-inch specimen captured by the "Albatross" off the Santa Barbara Islands of southern California (Gilbert, 1890). Other specimens have been reported as far north as the Bering Sea (Rathbun, 1892; Gilbert, 1895). The species is systematically grouped, with the varieties of rockfish characterized by a slightly convex to flat interorbital space, a strongly projecting symphyseal knob, and a moderately elongated body (Figure 1). Meristic and morphometric data as given by Phillips (1957) for *S. alutus* are shown in Table 1, and a general description of *S. alutus* as taken from Phillips follows.

General Description of *Sebastodes alutus*
(from Phillips 1957)

Body colour: Light red including fins; a dark olivaceous area on back under soft dorsal and a smaller dark area on caudal peduncle; some light olive stippling on sides.

Mouth and gill cavities: Mouth mainly pink, but with some duskiness; gill cavity pink, with considerable black blotching in adults.

Peritoneum: Gray with black dots or black.

Top of head, at mid-orbits: Slightly convex to flat.

Spines on top of head: Nasal, preocular, supraocular, postocular, tympanic and parietals usually present, but small and weak (a tympanic or supraocular spine may be absent occasionally). *Coronal and nuchal spines absent.*

Parietal ridges: Low and thin.

The five preopercular spines: Moderately strong, sharp, usually radially directed but sometimes with upper two directed backward.

The two opercular spines: Moderately strong, thin and sharp, the uppermost usually longer.

Supracleithral and cleithral spines: Strong to weak.

Lower margin of suborbital bone: Two small, sharply triangular spines, or rounded lobes present.

Lower posterior edge of gill cover: Spines present.

Symphyseal knob: A prominent, pointed, forward-projecting knob is present.

Raised patch of teeth on tip of lower jaw: A strongly raised patch of teeth present; not completely included by snout when jaws are closed.

End of maxillary: Under mid-orbit or rear of pupil.

Maxillaries: Covered with scales.

Table 1

Morphometric and meristic data on *Sebastodes alutus*

(from Phillips, 1957)

Measurement	Frequency of measurement into: Standard length	Frequency of measurement into: Head length	Frequency of orbit width into measurement
Length of head	2·6–2·8	– –	– –
Depth of body at origin of ventral fin	2·8–3·4	1·1–1·2	2·8–3·5
Depth of body at origin of anal fin	3·7–4·6	1·4–1·6	2·1–2·7
Length of base of anal fin	6·1–7·1	2·4–2·6	1·4–1·6
Length of snout	10·0–11·3	3·8–4·2	0·8–1·0
Width of orbit	9·3–10·1	3·4–3·8	– –
Width of interorbital space	– –	4·6–4·9	0·7–0·8
Width of suborbital bone	– –	– –	0·1–0·2
Length of upper jaw	5·6–6·2	2·1–2·3	1·6–1·8
Amount that lower jaw projects	– –	– –	0·2–0·4
Thickness of body	– –	– –	1·4–1·7
Width of base of pectoral fin	– –	– –	0·8–0·9
Longest pectoral fin ray	3·6–4·1	1·3–1·5	2·4–2·8
Longest ventral fin ray	– –	1·8–2·0	1·8–2·1
Length of ventral fin spine	– –	2·9–3·4	1·0–1·2
Length of first anal fin spine	– –	– –	0·4–0·6
Length of second anal fin spine	8·3–10·8	3·5–4·2	0·9–1·0
Length of third anal fin spine	– –	– –	0·9–1·1
Longest anal fin ray	5·9–6·6	2·3–2·4	1·5–1·6
Longest dorsal fin spine	7·9–8·9	2·9–3·4	1·1–1·2
Longest dorsal fin ray	6·7–7·8	2·5–2·9	1·2–1·5
Least depth of caudal peduncle	10·6–12·3	4·1–4·5	0·8–1·1
Ventral length of caudal peduncle	– –	1·8–2·0	1·8–1·9
Dorsal length of caudal peduncle	– –	2·5–2·8	1·3–1·5
Posterior of anus to origin of anal fin	– –	– –	0·3–0·6
Longest raker on first gill arch	– –	– –	0·4–0·6

Number of rays in dorsal fin	14 or 15 (rarely 16 or 17)
Number of rays in anal fin	8 or 9
Number of rays in each pectoral fin	18 (occasionally 17)
Unbranched rays in each pectoral fin	8 (occasionally 5, 7, or 9)
Number of rakers on first gill arch	33–38
Number of pores in lateral line	44–51
Diagonal rows of scales below lateral line	49–55
Number of specimens examined	11, plus 4
Size of specimens examined	13·0–17·8 inches

Mandibles: Covered with scales.

Branchiostegals: With scales.

Ends of pectoral and ventral fins: Tips of pectorals extend to tips of ventrals, or slightly beyond, sometimes reaching anus.

Second anal fin spine: Usually twice as thick as third, occasionally only slightly thicker. Tip of second fails to reach tip of third by about one-sixth of orbit width (spines depressed).

Spinous dorsal fin membrane: Moderately incised.

Posterior profile of caudal fin: Strongly indented.

Terminal profile of anal fin: Nearly vertical, or with slight posterior slant.

Jordan and Evermann (1898) indicate a close taxonomic relationship between *S. alutus, S. miniatus, S. proriger,* and *S. brevispinis.* The relation to *S. miniatus* and *S. brevispinis* was not considered significant by Alverson (1954), since they differ conspicuously from *S. alutus* in osteology, morphology, and colour. We believe *S. alutus* is more closely allied to *S. saxicola* than other species. Field differentiation between these species is difficult.

History of the Fishery

Pacific ocean perch, *Sebastodes alutus,* were known to be available off the Washington and the Oregon coasts a number of years prior to commercial exploitation. Trawl fishermen who occasionally made catches of this species when fishing near the continental slope sorted the largest fish from the haul and returned the others to the sea. The retained catch was sold along with other *Sebastodes* under a number of market names including rockcod, rockfish, and snappers. Fishermen, however, generally avoided grounds inhabited by small (less than 15 inches in length) scorpaenids such as *S. alutus,* as the buyers usually would not accept these species.

Historical notes of the west coast "ocean perch" fishery, chronologized by Alverson (1954) and Westrheim (1958), indicate that active exploitation of the fishery began in 1946. During 1946 and in early 1947 small quantities of *S. alutus* purchased by the Yaquina Bay Fish Company of Newport, Oregon, were filleted and sold as fresh fish. The manager of the company, D. W. Turnacliff, noted the close similarity between the east coast ocean perch and the newly exploited west coast deep-water rockfish and initiated labelling frozen fillets as "ocean perch" late in 1947. The packaged and labelled product at that time contained *S. alutus,* a considerable amount of the split-nosed rockfish, *S. diploproa,* and a comparatively unknown species, *S. crameri.* The vernacular applied by fishermen to the small, red, deep-water rockfishes was "rosefish", and no attempt was made to differentiate species within the heterogeneous catch. Following the labelling of the fillets as "ocean perch", landings of "rosefish" (mainly *S. alutus*) greatly increased.

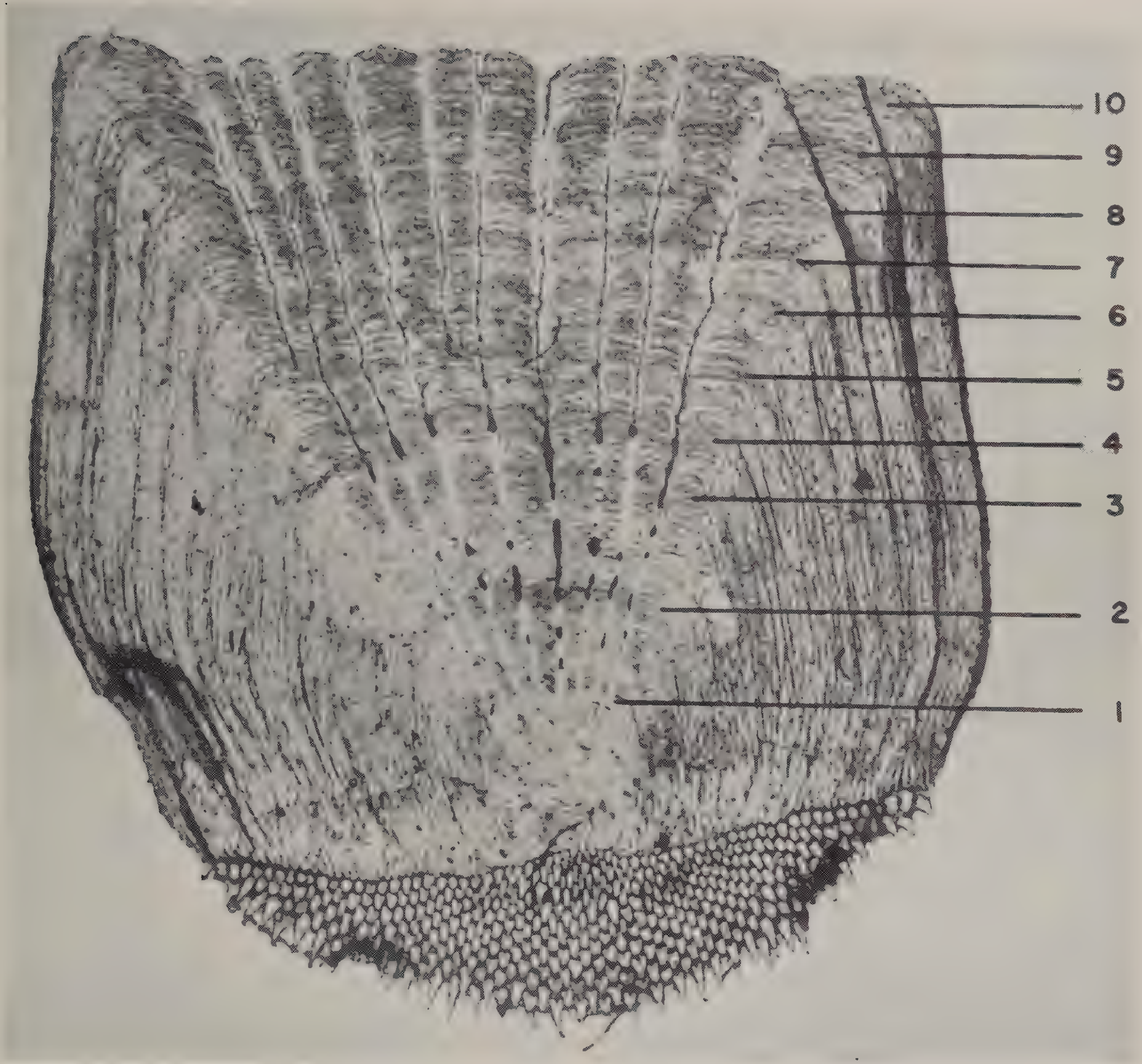

Figure 2. Photograph of a scale taken from a Pacific ocean perch, 364 mm fork length, and showing 10 annuli.

The new fishery, which for several years remained a lone venture of the Yaquina Bay Fish Company, was confronted with a set-back in 1949 when an interstate shipment of Pacific ocean perch was seized by the U.S. Food and Drug Administration*. Libel action was then initiated against the company for using the label "ocean perch". Prior to the trial, an "ocean perch" committee was organized to acquaint the U.S. Food and Drug Administration with the taxonomic similarities of the two genera *Sebastodes* and *Sebastes* and the close taxonomic position of the species *Sebastodes alutus* and *Sebastes marinus*.

Testimonies concerning the taxonomy of the species, which demonstrated a divergence of opinion of the experts as to the validity of generic differences, must have thoroughly confused the authorities. The case was never tried, and in June of 1951 permission was granted to market *S. alutus* as "Pacific ocean perch". Other members of the genus *Sebastodes* were not authorized for interstate shipment under this trade name.

Subsequent to this ruling the fishery expanded rapidly. Fishermen prospected grounds to the north and south of the area off central Oregon, and other fish processors began accepting Pacific ocean perch. Successful exploratory fishing surveys conducted aboard the Fish and Wildlife Service's vessel, "John N. Cobb" (Alverson 1951-1953), also helped to expand and accelerate development of the fishery. By 1955, deep-

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* The United States Food and Drug Administration may prohibit shipment between states of produce which it considers to be falsely labelled.

Table 2

Pacific coast landings (pounds) of Pacific ocean perch[1]

Year	California	Oregon	Washington	British Columbia	Total
1946	–	97,000	–	–	97,000
1947	–	164,000	–	–	164,000
1948	–	211,000	–	–	211,000
1949	–	1,044,000	–	–	1,044,000
1950	–	1,525,000	–	–	1,525,000
1951	–	1,856,000	–	–	1,856,000
1952	–	4,737,000	1,696,000	–	6,433,000
1953	–	2,647,000	3,102,000	407,000	6,158,000
1954	–	3,761,000	6,672,000	481,000	10,914,000
1955	57,000	1,637,000	3,499,000	72,000	5,265,000
1956	7,000	3,115,000	4,996,000	295,000	8,413,000
1957	–	3,328,000	4,549,000	243,000	8,120,000

[1] Sources of statistics include Washington State Department of Fisheries, Oregon Fish Commission, Pacific Marine Fisheries Commission, and the Yaquina Bay Fish Company.

water banks (100 to 200 fathoms) between northern California and Queen Charlotte Sound, British Columbia, had been prospected. Although much of the continental slope was found "untrawlable", excellent perch grounds were located off the Columbia River, northern Washington, and central Vancouver Island, and in Queen Charlotte Sound. Some of the more productive Pacific ocean perch grounds currently exploited are shown in Figure 3. All of these grounds yielded excellent catches during initial fishing, but fell off somewhat following a reduction in the accumulated stock levels. The largest and most productive perch grounds currently (1955/59) being fished lie at the north end of Vancouver Island in Queen Charlotte Sound.

The fishery for Pacific ocean perch has been pursued almost exclusively by trawlers fishing out of the States of Oregon and Washington, although trawlers from the State of California and from the Province of British Columbia, Canada, make occasional landings. Availability of commercial quantities of *S. alutus* off California is apparently limited to the northern part of the state, and although large concentrations of Pacific ocean perch are known to exist off Vancouver Island, Canadian fishermen have not yet exploited this species intensively. Annual Pacific coast landings of "perch" in recent years (1952/1957) have ranged from 5·3 to 10·9 million pounds (Table 2). During this same period total trawl landings for all species along the Pacific coast ranged from 107 to 142 million pounds (unofficial figures of the Pacific Marine Fisheries Commission).

Although the growth of the west coast "ocean perch" fishery appears to have been largely influenced by the marketing problem, the expansion of trawling and prospecting of the offshore banks was imminent. In this, the adoption of various electronic devices developed and modernized during World War II played a major role. The use of echo-sounders and loran were significant post-war changes in both the Washington and the Oregon fleets. With accurate offshore navigation and the ability to survey bottom contours quickly, the small trawlers became proficient in locating and maintaining their position on the deep-water perch grounds. Details concerning the evolution of gear and fishing methods for west coast trawling have been described by Scofield (1948), Harry (1956), and Alverson (1959).

Trawling for Pacific ocean perch has been carried out at depths ranging from 50 to 300 fathoms (92 to 549 metres); however, the bulk of the catch is taken at depths ranging from 80 to 200 fathoms (146 to 366 metres). Studies of annual bathymetrical catch distributions for *S. alutus* were conducted by the Washington State Department of Fisheries during the period 1955 through 1957. Catches for these years are graphed to show the vertical catch distribution in each 10-fathom interval (Figure 4). The quantity, the percentage of the total catch, and the cumulative percentage of catch for these depth increments are given in Table 3. The largest production, at present, is obtained at depths between 100 and 160 fathoms (183 to 293 metres). Westrheim's (1958) data for the Oregon fishery indicates a similar range.

The average catch per hour for Washington trawlers working perch grounds has, in recent years, ranged between 800 and 2,000 pounds[1]. Studies of yield per hour by area show a general increase toward the northern extremity of the geographical fishing range (these grounds are the most distant from U.S. fishing ports)[2].

The continental slope, throughout the present range of the fishery, is comparatively steep and even the available trawling grounds within the species' depth range are not equivalent in area to those of the North Atlantic. The species' range extends from southern California to the Bering Sea but has not been recorded along the Asiatic coast.

It seems doubtful that the production potential of Pacific ocean perch is comparable to that of *Sebastes*; however, present catches are taken from a relatively small portion of the known range of the species, and total landings have been influenced by market demand rather than abundance or availability of the species. Recent U.S. Fish and Wildlife Service exploration in Alaskan waters (Schaefers, *et al.*, 1955; Greenwood, 1958) have shown *S. alutus* to be abundant off southeastern Alaska and in the Gulf of Alaska off Prince William Sound. Further studies will probably demonstrate commercial abundance of the species along the Aleutian Islands. These unexploited areas offer considerable prospects for expansion of the existing fishery.

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[1] Estimates by Washington State Department of Fisheries and Oregon Fish Commission.

[2] This trend may be influenced to some extent by greater efficiency or fishing power of vessels fishing the northern grounds.

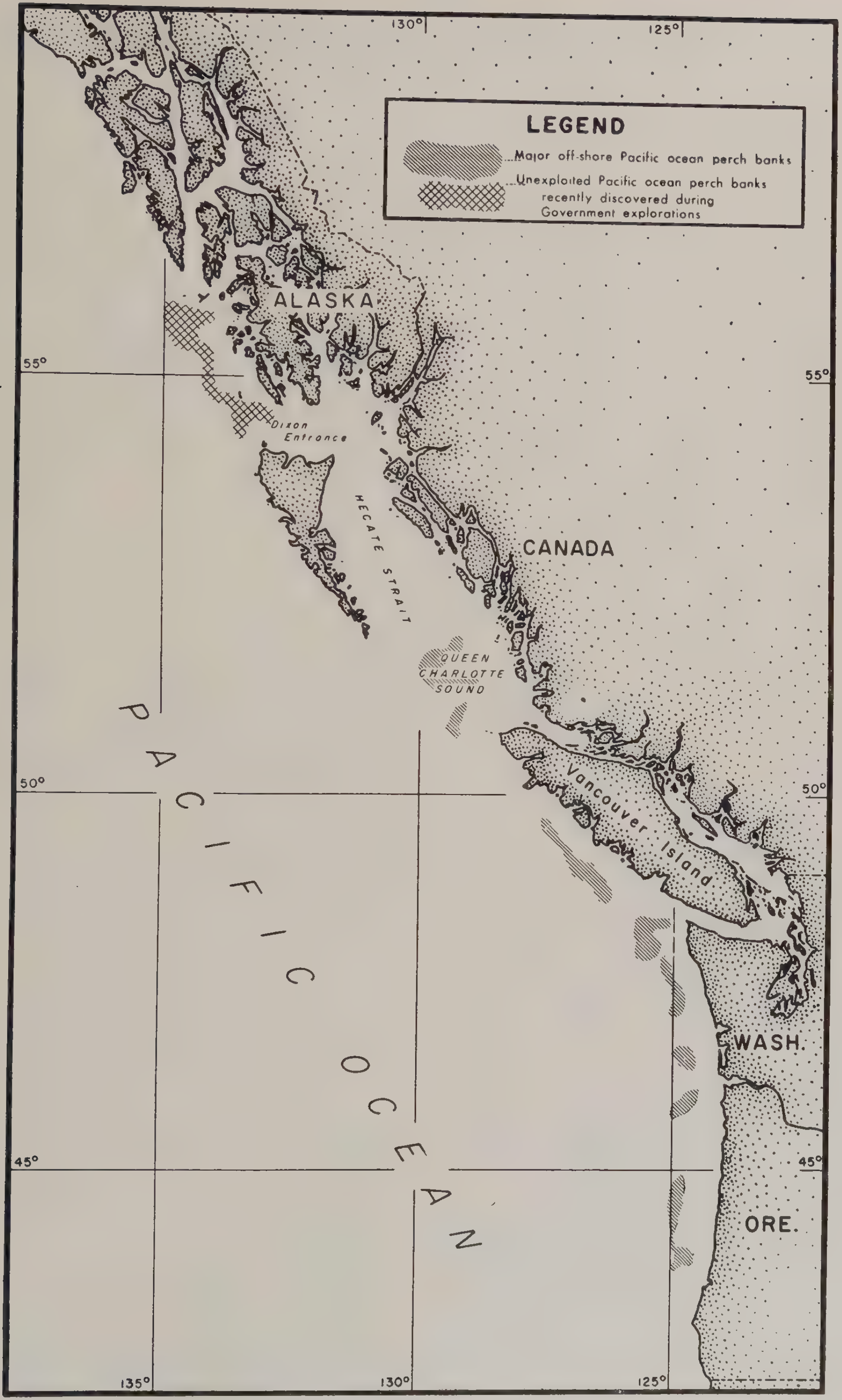
LEGEND
▨ Major off-shore Pacific ocean perch banks
▩ Unexploited Pacific ocean perch banks recently discovered during Government explorations
130°
125°
135°
55°
50°
45°
ALASKA
CANADA
Dixon Entrance
HECATE STRAIT
QUEEN CHARLOTTE SOUND
Vancouver Island
WASH.
ORE.
PACIFIC OCEAN

Figure 3. Major west coast Pacific perch fishing grounds.

Table 3

Catch, percentage of total catch, and cumulative percentage by 10-fathom intervals for Pacific ocean perch

(all offshore areas, 1955 - 1957)

Depth in fathoms	Catch in 1000s of pounds			% of total catch			Cumulative catch by %		
	1955	1956	1957	1955	1956	1957	1955	1956	1957
<51	11·5	8·5	5·2	0·4	0·2	0·1	0·4	0·2	0·2
51–60	9·7	5·0	6.1	0·4	0·1	0·2	0·8	0·3	0·2
61–70	25·5	14·0	122·6	0·9	0·4	3·0	1·7	0·7	3·2
71–80	130·1	8·5	79·6	4·7	0·2	1·9	6·4	0·9	5·1
81–90	167·4	117·3	159·2	6·1	3·1	3·9	12·5	4·0	9·0
91–100	252·7	181·9	45·4	9·2	4·9	1·1	21·7	8·9	10·1
101–110	505·9	448·8	516·4	18·4	12·0	12·6	40·1	20·9	22·7
111–120	212·5	299·6	563·4	7.7	8·0	13·8	47·8	28·9	36·5
121–130	199·0	1043·8	889·9	7·2	28·0	21·8	55·0	56·9	58·3
131–140	127·7	469·0	549·0	4·6	12·6	13·4	59·6	69·5	71·7
141–150	390·8	323·1	131·9	14·2	8·7	3·2	73·8	78·2	74·9
151–160	315·3	465·5	256·0	11·4	12·5	6·3	85·2	90·7	81·2
161–170	80·7	124·1	159·3	2·9	3·3	4·0	88·1	94·0	85·2
171–180	111·3	61·8	205·0	4·0	1·7	5·0	92·1	95·7	90·2
181–190	145·8	48·6	226·0	5·3	1·3	5·5	97·4	97·0	95·7
191–200	35·8	22·5	113·1	1·3	0·6	2·7	98·7	97·6	98·4
201–210	12·0	44·7	14·4	0·4	1·2	0·3	99·1	98·8	98·7
211–220	8·9	18·1	39·0	0·3	0·5	1·0	99·4	99·3	99·7
221–230		9·1	3·0		0·2	0·2		99·5	–
231–240	3·5	6·6	0·1	0·1	0·2	–	99·5	99·7	–
241–250	4·0		0·1	0·2			99·7		
>250	5·0	10·5	–	0·2	0·4	–	99·9	100·0	–
Total	2755·1	3731·0	4084·7	100·0	100·0	100·0	100·0	100·0	100·0

Contemporary catches are therefore probably but a small fraction of the potential of the fishery.

Related species

Species of *Sebastodes* commonly taken in trawls along with catches of *S. alutus* include: *saxicola, crameri, aleutianus,* and *diploproa. Sebastodes saxicola* has a smaller average size than *alutus,* and because of its small size (the average length taken by trawlers is about 10 inches, or 25·4 cm), only a fraction of those available on the grounds are captured.

Sebastodes crameri was a rare and relatively unknown species prior to the inception of the Pacific ocean perch fishery. Following the expansion of trawling to the deeper waters of the continental slope, *crameri* was found to be common and is now a commercially-marketed species. This species, although it has not been found to be as abundant as *alutus,* has been noted throughout the bathymetric and the geographic range where Pacific ocean perch are now fished. *S. crameri* is relatively deep-bodied, and its average size is somewhat larger than *S. alutus.*

S. aleutianus, one of the largest varieties of rockfish taken during perch fishing, may attain weights exceeding 25 pounds. The larger specimens of the species are normally taken by trawlers fishing at depths exceeding 150 fathoms (275 m) and are common at depths exceeding 200 fathoms (366 m). Alverson (1954) reports good catches of *aleutianus* were made during deep-water explorations off the Washington coast.

S. diploproa, the split-nosed rockfish, is the most common species of *Sebastodes* associated with catches of *alutus.* It is easily identified by projections of the premaxillaries which have prominent dentiguous knobs. The species attains a size somewhat larger than *saxicola,* but smaller than *alutus.*

Management problems

Management problems for Pacific ocean perch have been practically non-existent. Economic conditions appear to be the limiting factor in the total production of this species. The promulgation of a minimum mesh size regulation for trawl nets (4·5 inches or 11·4 cm, stretch measure between knots) caused considerable difficulty when it was found that the Pacific ocean perch could not be fished properly with so large a mesh size. Provisions have now been made to permit Pacific ocean perch trawlers to use a smaller mesh size (3·0-3·5 inches between knots). Savings-gear experiments and subsequent regulations were coordinated and recommended by the Pacific Marine Fisheries Commission.

Technology

It may seem peculiar that of the 55 known species of rockfish, *S. alutus* alone has recently gained prominence as an important commercial fish. Rockfish have been landed in quantity by trawl and line fishermen for a number of years. Various species have dominated rockfish catches, depending on regional preferences and availability. A large portion of the catch has been sold on the fresh fish market, and some quantity has been sold as frozen fillets.

The commercial species of rockfish differ in flavour, texture, and time the fillets may be retained as a frozen product. Some of the major factors influencing and handicapping the market acceptance of frozen rockfish fillets have been the comparatively poor keeping quality, the development of off-colour, rancidity, and undesirable changes in flesh texture. Technological studies concerning the keeping qualities and cold-storage life of various rockfish, conducted by the U.S. Fish and Wildlife Service (Miyauchi and Stansby, 1952; and Miyauchi and Alverson, 1955), have demonstrated *S. alutus* to be superior to other rockfish tested. A comparison of fillets of *S. alutus* and *Sebastes marinus* indicated the two species were "similar in appearance, flavour, and texture throughout most of their cold-storage life". The relatively good freezing qualities of *alutus* have therefore increased their value in the frozen-fish trade.

A major problem confronting the Pacific bottom-fish industry has been the parasitization of rockfish. With the Pacific ocean perch this has been especially important, as a large portion of the catch is sold to the United States military forces who require the fillets of fish to be largely free of parasites. Stern and Liston (1958) report the most common muscle parasite of *S. alutus* "appears" to be the trematode *Prosorhynchus.* The larval stage of this parasite forms pale yellow to black cysts (spots) in the muscle tissue which are 2 to 5 mm in length. The incidence of parasitization, which varies with the area of capture, may range from 15 to 90 % of the catch. Objections to the parasite in fish destined for human consumption are apparently based on aesthetic grounds, as there is no evidence that this trematode can infect man.

General Biology

The taxonomic difficulties of species identification, the relatively subordinate position rockfish play in the Pacific coast fisheries, and the cost of collecting various stages of rockfishes at sea have resulted in a paucity of information concerning the life histories of species of the genus *Sebastodes.* Of the 55 or more varieties known to exist off the coast of western North America, only two have been studied in any detail. Wales (1952) studied the life history of the blue rockfish *Sebastodes mystinus* and Westrheim (1958) has published data on the biology of the Pacific ocean perch *S. alutus.* The post-war development of the Pacific ocean perch fishery fostered interest in this species, and a greater effort has been made by biologists to collect information concerning the species. As a result, probably more is known concerning the biology of this rockfish than all other *Sebastodes.* The knowledge however, even with this species, is fragmentary.

Early life history

The Pacific ocean perch is an ovoviviparous species similar to other members of the *Sebastodes* and *Sebastes* groups. Westrheim (1958) reports that the young are released during the months of January and February, although there are indications that "spawning" or release of young may commence as early as October and extend through March.

The bathymetric and the geographic distribution of the young has not been established. Large numbers of young *S. alutus* ranging from 20 to 50 mm in length have, however, been found in the stomach of albacore tuna, *Thunnus germo,* caught during the summer months several hundred miles off the Oregon and the Washington coasts (Powell and Hildebrand, 1950; Powell, *et al.*, 1952). In one instance four albacore stomachs yielded 487 small *Sebastodes.* Approximately 85 % of the small rockfish taken from albacore stomachs during the studies conducted in 1950 were identified as *S. alutus.* Most of the small *S. alutus* ranged between 20 and 30 mm in length. These fish are presumed to be the progeny of females who "spawned" during the preceding winter.

In many instances the young of *S. alutus* taken from stomachs were in excellent condition, and at times they were regurgitated alive. Young Pacific ocean perch have also been collected at sea with dip nets, and occasionally have been observed to "ball" at the surface in the manner of herring. Mid-water trawl studies conducted in the Gulf of Alaska have yielded young *Sebastodes* as small as 6 mm in length at distances up to 300 miles from shore (Aron, 1958). Their identity has not been established.

The young of *S. alutus* appear to lead a pelagic existence dispersed in offshore waters at considerable distances from the fishing banks where adults are captured. Although the vertical distribution of the young has not been established, the observations of surface schooling by them and the regurgitation of living young by albacore indicate that they inhabit surface waters at least during daylight hours.

The colour pattern of young *S. alutus* taken during their pelagic life is similar to that of other pelagic fishes, i.e., greenish-blue dorsally and silvery on the ventral surfaces. A deep purple blotch is present on the cheek of the young. The body colours become a light rust-brown dorsally and white ventrally when specimens are preserved. Age at which transition from the pelagic to demersal state might take place is a matter of conjecture. We speculate, however, from the size ranges of perch collected from trawl grounds that the transition may occur during the 2nd or 3rd year of life.

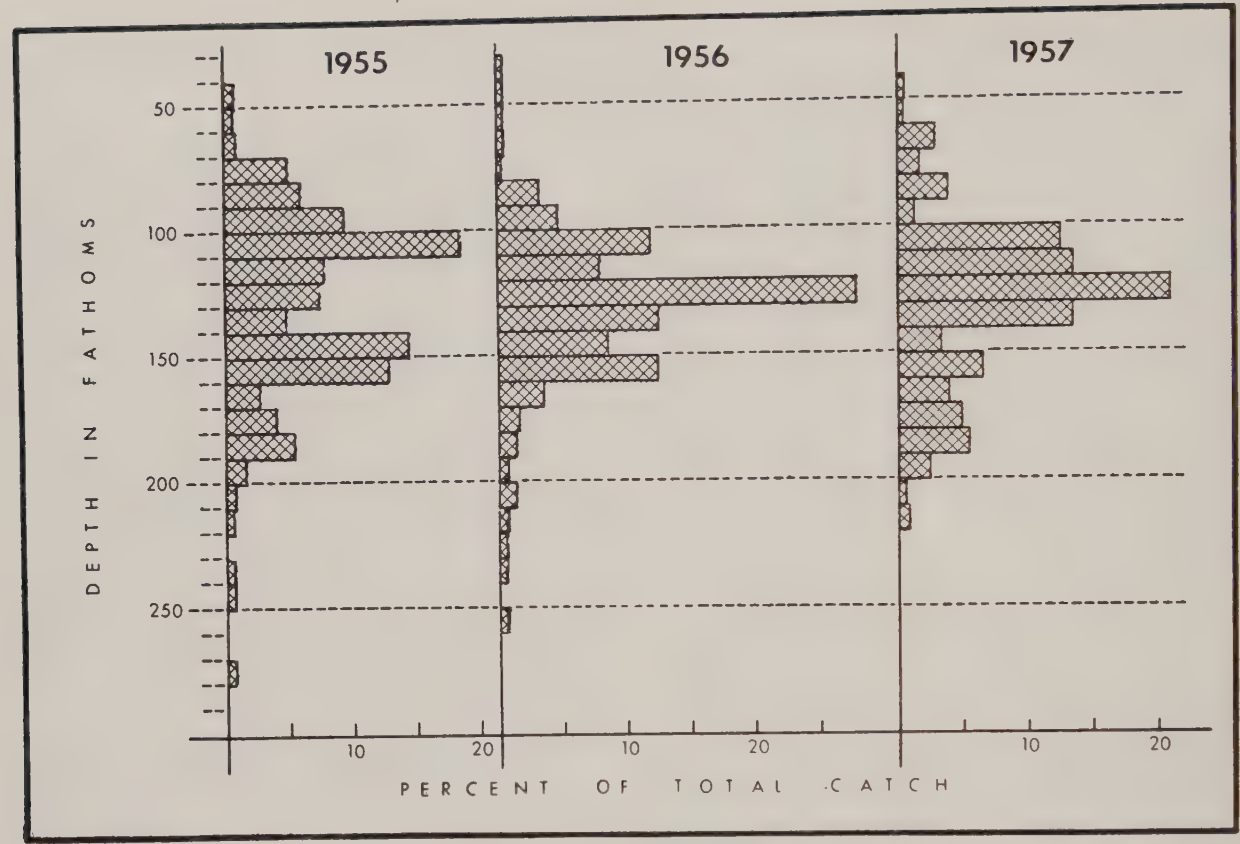

Figure 4. Percentage total catch of Pacific ocean perch in 10-fathom intervals, as recorded for Washington trawl vessels, all areas, 1955–1956–1957.

Table 4
Relationship between scale ring count and body length for 229 male Pacific ocean perch

Fork length (cm)	Scale ring count 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Total
18	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
.																			
.																			
.																			
28	–	–	1	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	2
29	–	–	–	–	–	–	–	1	0	–	–	–	–	–	–	–	–	–	1
30	–	–	–	1	2	1	–	0	0	–	–	–	–	–	–	–	–	–	4
31	–	–	–	–	2	2	2	3	1	–	–	–	–	–	–	–	–	–	10
32	–	–	–	–	1	3	3	2	0	–	–	–	–	–	–	–	–	–	9
33	–	–	–	–	1	2	5	5	4	1	–	–	–	–	–	–	–	–	18
34	–	–	–	–	–	1	2	7	11	2	–	–	–	–	–	–	–	–	23
35	–	–	–	–	–	0	2	5	5	6	2	–	–	–	–	–	–	–	20
36	–	–	–	–	–	0	1	6	6	9	6	1	1	–	1	–	–	–	31
37	–	–	–	–	–	0	2	5	5	9	7	8	3	1	1	–	–	–	41
38	–	–	–	–		0	0	2	6	2	6	8	2	2	2	1	–	–	31
39	–	–	–	–	–	0	2	1	0	3	1	4	2	6	–	0	–	–	19
40	–	–	–	–	–	1	–	2	2	1	1	2	2	–	–	1	–	–	12
41	–	–	–	–	–	–	–	–	–	1	0	0	1	–	–	1	–	–	3
42	–	–	–	–	–	–	–	–	–	–	1	1	0	–	–	–	–	1	3
43	–	–	–	–	–	–	–	–	–	–	–	–	0	–	–	–	–	–	0
44	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	1
Total	1	0	1	1	6	10	19	39	41	34	24	24	12	9	4	3	0	1	229

Table 5

Relationship between scale ring count and body length for 304 female Pacific ocean perch

Fork length (cm)	Scale ring count 6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	>20*	Total
27	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
28	–	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
29	–	0	–	1	–	–	–	–	–	–	–	–	–	–	–	–	1
30	–	0	–	0	–	–	–	–	–	–	–	–	–	–	–	–	0
31	1	0	2	0	1	–	–	–	–	–	–	–	–	–	–	–	4
32	0	1	2	1	1	–	–	–	–	–	–	–	–	–	–	–	5
33	0	3	0	3	0	2	–	–	–	–	–	–	–	–	–	–	8
34	1	2	5	3	1	3	1	–	–	–	–	–	–	–	–	–	16
35	–	2	4	3	4	1	1	1	–	–	–	–	–	–	–	–	16
36	–	1	2	5	5	4	4	0	–	–	1	–	–	–	–	–	22
37	–	–	2	3	6	12	5	1	1	1	1	–	–	–	–	–	32
38	–	–	2	4	6	9	11	8	3	2	1	1	–	–	–	–	47
39	–	–	–	–	3	10	10	5	3	2	1	0	–	–	–	–	34
40	–	–	–	–	3	7	3	8	2	4	3	2	–	1	–	–	33
41	–	–	–	–	1	2	6	4	2	3	3	2	3	1	–	–	27
42	–	–	–	–	–	1	0	1	3	0	4	1	2	1	1	2	16
43	–	–	–	–	–	1	1	–	3	2	1	2	1	1	2	3	17
44	–	–	–	–	–	–	1	–	–	0	4	0	3	2	0	1	11
45	–	–	–	–	–	–	–	–	–	2	2	1	2	–	2	0	9
46	–	–	–	–	–	–	–	–	–	–	2	–	–	–	0	1	3
47	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0	1	1
48	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	1
Total	2	10	19	23	31	52	43	28	17	16	23	9	11	6	6	8	304

* Ring Count/Length: 22/42; 22/43; 22/43; 22/44; 24/43; 24/46; 25/42; 27/47.

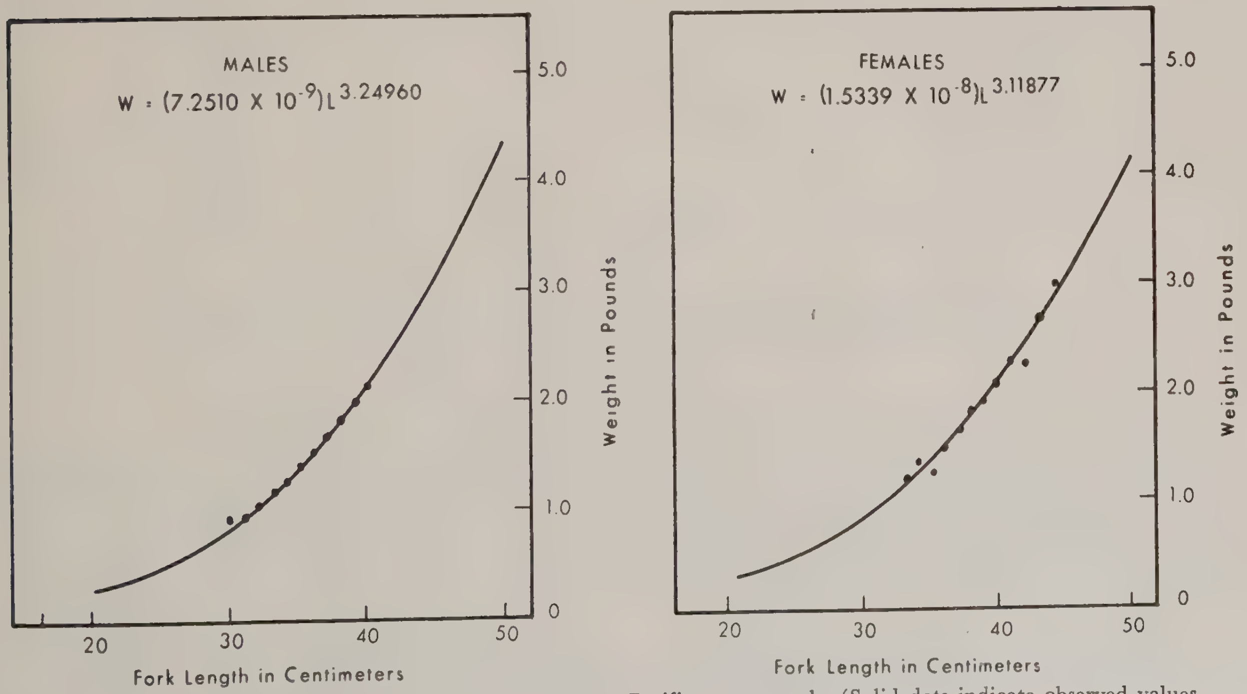

Figure 5. Length/weight relationship for male and female Pacific ocean perch. (Solid dots indicate observed values from which each curve was calculated).

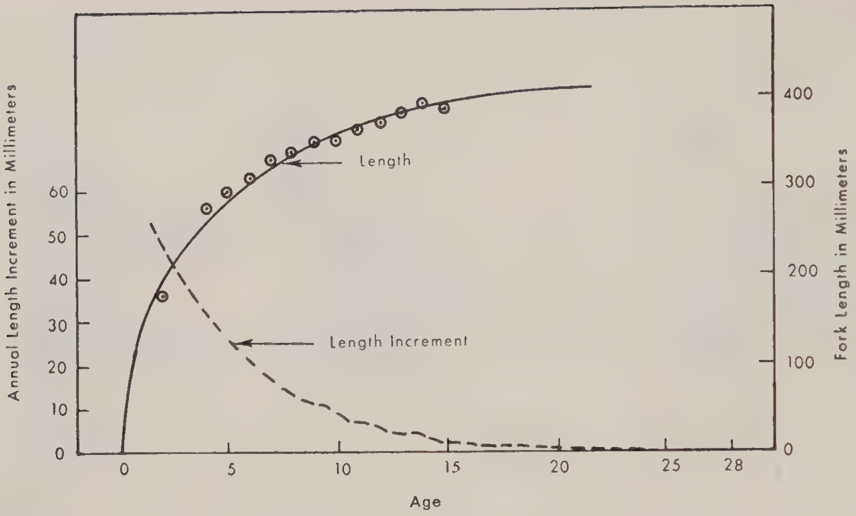

Figure 6. Age/length relationship for male Pacific perch, based upon the Bertalanffy method of growth analysis. (Circled dots indicate observed values obtained from the direct method of growth analysis).

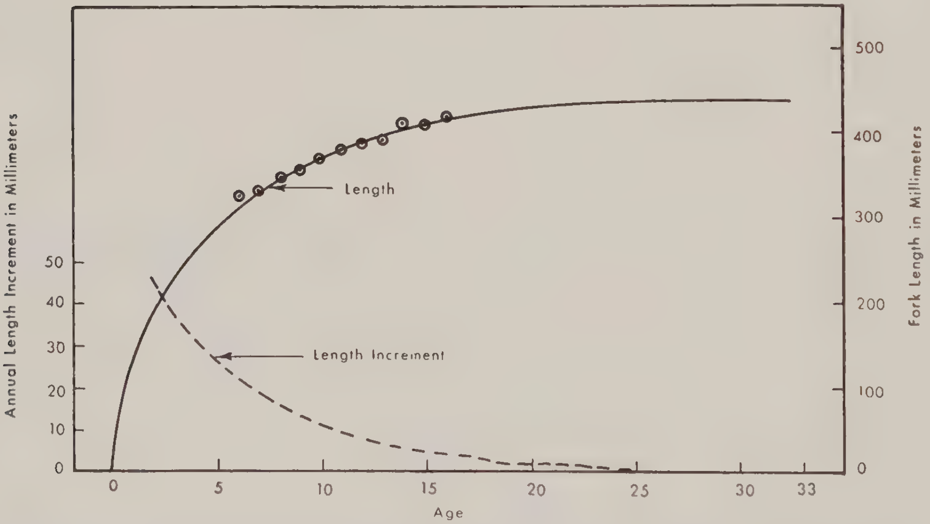

Figure 7. Age/length relationship for female Pacific ocean perch, based upon the Bertalanffy method of growth analysis. (Circled dots indicate observed values obtained from the direct method of growth analysis).

Age and growth

The section on age and growth as well as the following section dealing with mortality and fecundity represent summaries of results obtained by Westrheim (1958). Length-weight relationships for Pacific ocean perch by sex were determined from a sample of 244 males and 230 females (Figure 5). The derived formulae are:–

Males: $W = (7{\cdot}2510 \times 10^{-9})L^{3{\cdot}24960}$

Females: $W = (1{\cdot}5339 \times 10^{-8})L^{3{\cdot}11877}$

where W = weight in pounds and L = fork length in millimetres.

Table 6

Bertalanffy constants calculated from Pacific ocean perch growth data obtained from the scale method of growth analysis

Constants	Scale method	
	Males	Females
t	1–14	1–14
L_∞	403 mm	432 mm
K	0·20	0·18
W_∞	2·06 lb	2·54 lb
t_0	–0·71 year	–1·09 year
t_λ	29 years	34 years

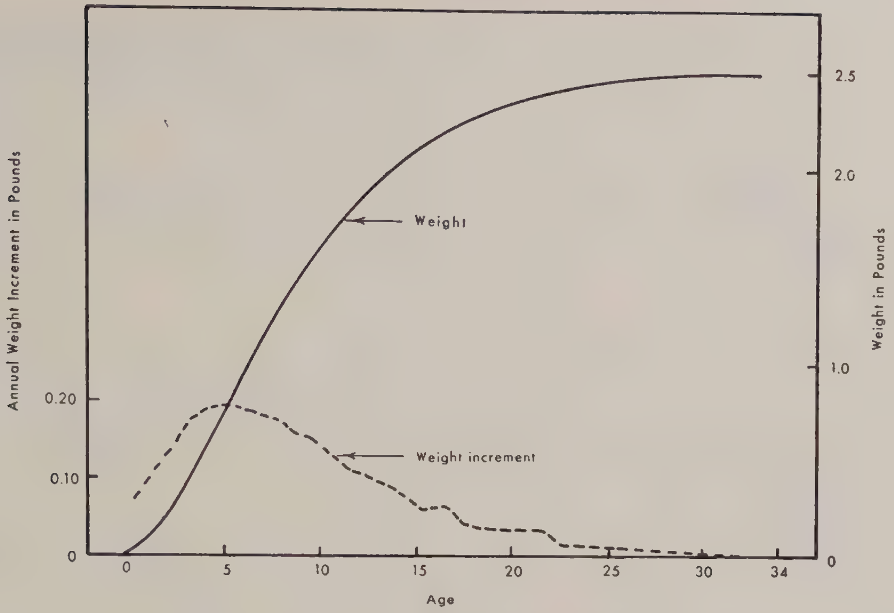

Figure 8. Age/weight relationship for male Pacific ocean perch, based upon the Bertalanffy method of growth analysis.

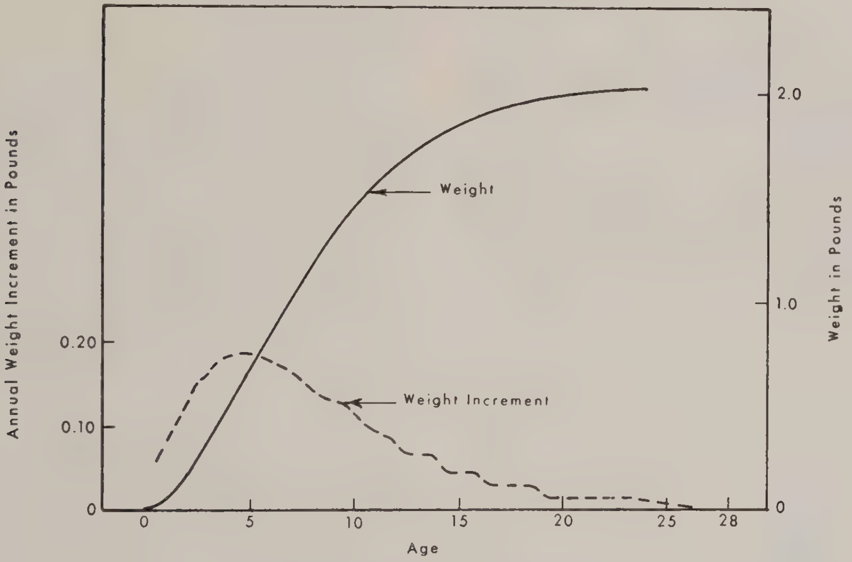

Figure. 9. Age/weight relationship for female Pacific ocean perch, based upon the Bertalanffy method of growth analysis.

Age determination of Pacific ocean perch was attempted using dry-mounted scales (Figure 2). A total of 533 readable scales was obtained from fish sampled in the Oregon trawl landings during the period 1950-1953. The readability of the scales was only fair. Multiple readings by one reader of each scale produced a percentage agreement of 70. The percentage agreement varied inversely with size of fish and number of rings on the scale. Reliability of the scale readings was imperfectly demonstrated, because the absence of juvenile fish hindered this study[1]. The annulus is apparently formed during the winter months.

Tabulations of the age-length relationship by sex obtained from the 533 scales are given in Tables 4 and

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[1] At the time of this study the author considered the first annulus indicated in Figure 2 as doubtful. Therefore it was not used in the age and growth analysis. Subsequent data now indicate that this decision may have been in error. Thus, the Pacific ocean perch included in this study may be one year older than indicated.

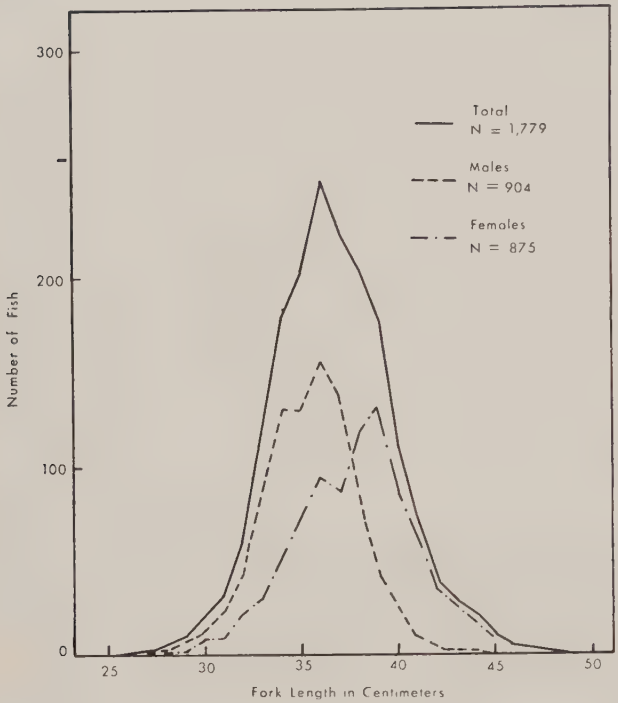

Figure 10. Length-frequency polygons for 904 male and 875 female Pacific ocean perch samples from Oregon trawl landings during the period September 1950 through September 1952.

5. The absence of juvenile fish is evident. Age-length relationships (Figures 6 and 7) established by extrapolation from scale measurements were used to perform a Bertalanffy growth analysis (Table 6). Figures 8 and 9 show the age-weight relationships for male and female Pacific ocean perch.

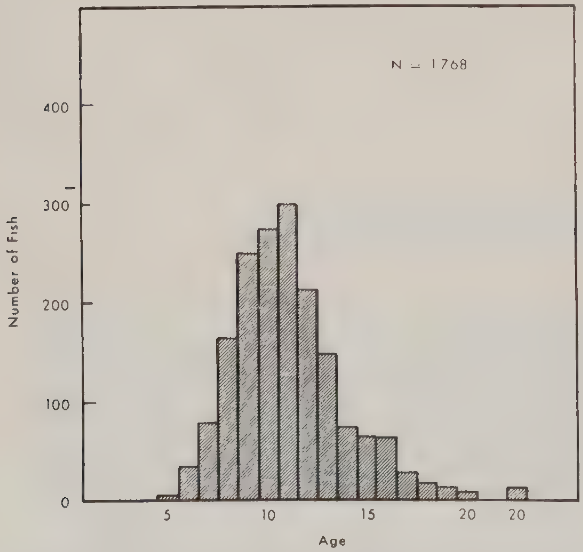

Figure 11. Calculated age-frequency histogram of Pacific ocean perch, sexes combined, for the sampling period September 1950 through September 1952.

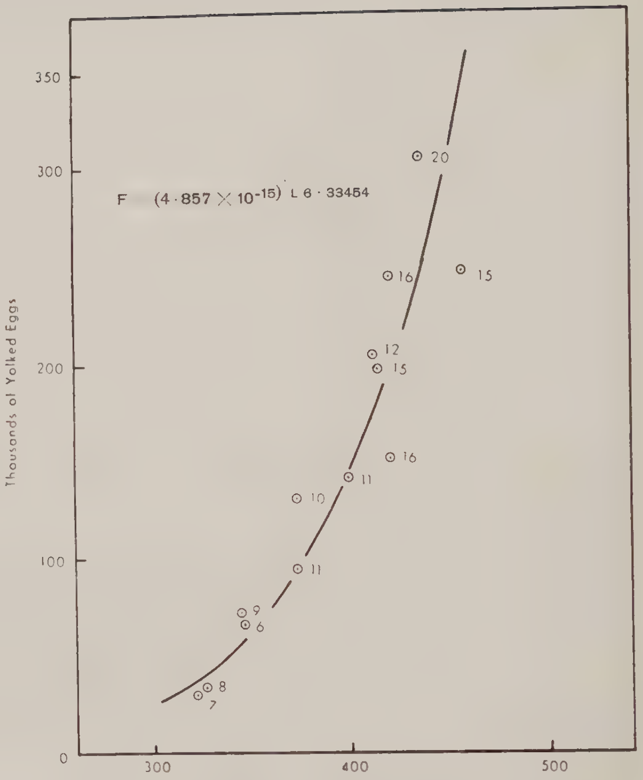

Figure 12. Fecundity/length relationship for female Pacific ocean perch. (Circled dots indicate observed values, and numerals indicate age of each fish.)

These data indicate that growth is very slow, particularly after the 10th year of life and the life span may exceed 30 years. These conclusions, of course, depend upon the validity of the age determinations.

Mortality

The size composition of the trawl catches of Pacific ocean perch is shown in Figure 10. The fork lengths ranged from 25 to 48 cm, and the mean length (sexes combined) was 371 mm. The mean length of males (359 mm) was smaller than for females (381 mm). The age composition (sexes combined) of the catch is shown in Figure 11. The histogram indicates that fish are probably not fully recruited to the fishery until age 11 or 12. Since the fishery did not begin to remove appreciable quantities of perch from the stock until 1949 (1–3 years before these data were collected), the descending line of the histogram should be representative of survival of the *unexploited population*. From these data an estimate was obtained of the total mortality rate[1] (or natural mortality) prior to the inception of the fishery. A semi-log transformation of these data and subsequent regression analysis yielded an estimated annual natural mortality rate of 32 %.

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[1] Assumes fishery has removed fully-recruited age-groups at an equal rate and recruitment was reasonably constant.

Maturity

Little direct information is available regarding size and age of Pacific ocean perch at maturity. Of 875 females examined only 18 (2·1 %) were immature (Westrheim, op. cit). The current fishery apparently is exploiting only the mature members of the stock.

Fecundity

A total of 13 pairs of ovaries was used to determine the length-fecundity relationship. The number of yolked eggs per fish was gravimetrically estimated. The length-fecundity relationship is shown in Figure 12. The observed values range from 32,400 eggs for a 324 mm fish (7 years) to 305,200 eggs for a 436 mm fish (20 years). The fecundity relationship is expressed mathematically by the formula:

$$F = (4{\cdot}857 \times 10^{-15}) L^{6{\cdot}33454}$$

where F = thousands of yolked eggs and L = fork length in millimetres.

Habitat description

Rockfish are found in waters ranging from a few fathoms deep to depths exceeding 900 fathoms. Pacific ocean perch are commonly found along the outer continental shelf and upper continental slope at depths from 80 to 250 fathoms (146 to 457 m). The species is common in and along the gullies, canyons, and submarine depressions of the upper continental slope. These areas are characterized by gravel or rocky bottom and frequently contain large boulders deposited during post-glacial periods. Alaska "coral", *Borganaria* sp., varieties of deep-water starfish, and sea urchins are typical invertebrate animals taken while trawling for Pacific ocean perch.

Information on seasonal or annual temperature patterns occurring in waters inhabited by *S. alutus* is scarce. Bathythermograph records taken during exploratory fishing cruises of the U.S. Fish and Wildlife Service indicate bottom temperatures in the areas of the present fishery range between 41 and 46 degrees Fahrenheit (5 to 7·8°C).

Behaviour patterns

Trawl fishermen who have had experience in fishing Pacific ocean perch report that the best catches of *S. alutus* are made during the "morning drag", just at sun-up. Drags made during the late morning and the afternoon also yield good catches, but are not generally of the magnitude of the morning drags. This, perhaps, reflects diurnal vertical shifts of the stock, which result in availability changes.

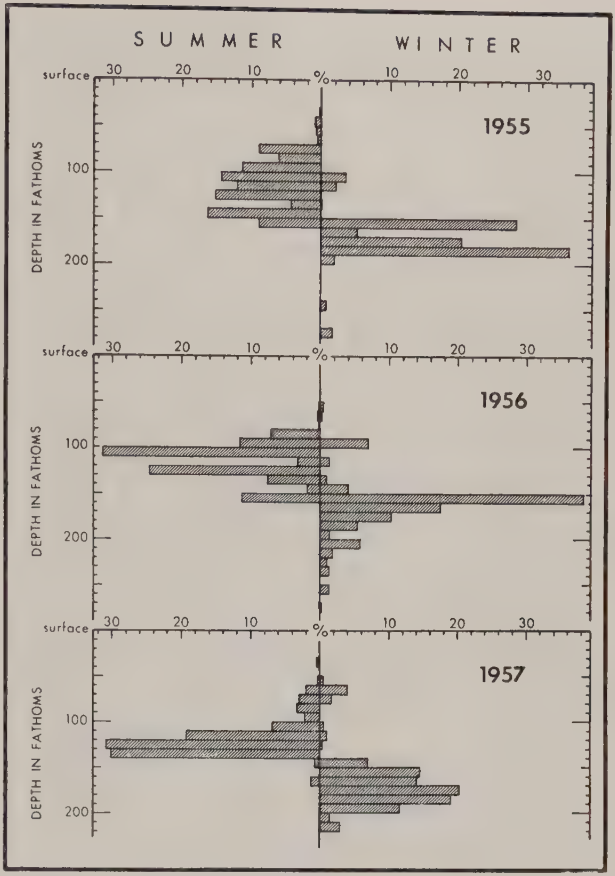

Figure 13. Percentage total catch of Pacific ocean perch, summer versus winter, in 10-fathom intervals, as recorded for Washington trawl vessels, all areas, 1955–1956–1957.

Studies of the catches by depth interval for the various seasons of the year indicate an offshore movement of *S. alutus* into deeper water during the winter months. A graphic comparison of the summer and the winter vertical catch distribution, as reported in 10-fathom intervals by Washington trawl fishermen for the years 1955 through 1957, is shown in Figure 13. These data are taken from interview records and represent about 70 % of the total landings. Opposing seasons, January through March and July through September, were arbitrarily selected to demonstrate the seasonal catch patterns. The catch by depth shows marked difference in the two periods contrasted: major summer catches were taken at depths between 80 and 160 fathoms while winter catches were taken at depths between 151 and 220 fms. The figure shown is a composite including all offshore banks exploited by trawlers of the State of Washington. The pattern, indicating a seasonal shift to deep water, is better defined when the study is restricted to individual banks. The illustrated seasonal shift to deep water is a qualitative effect which may reflect variations in seasonal distribution of effort by depth. The changes in seasonal availability by depth are, however, supported by a study of catch effort data through the same seasons and comparable depth ranges[1].

Some evidence of differential seasonal availability by sex was found by Westrheim (1958). During February and March males constituted 60–82 % of the landings. Subsequently the percentage of males declined to a low of 24–45 % during September. The period (February–March) in which males predominate coincides with the time the young are "born". The high percentage of males may indicate that the females are less available to the fishery at that time.

To date, west coast investigators have not attempted to study geographic migrations of *S. alutus*. Studies of quantitative parasitic infestation suggest that the stocks inhabiting the major offshore banks may be somewhat independent. Stern and Liston (1958) have shown a progressive increase in the numbers of *Prosorhynchus* sp. noted in the integument of *S. alutus* as the location of the catch moves northward.

There has been speculation by some authors that adult *S. alutus* may have a bathypelagic existence in offshore waters (Alverson, 1953; Alverson and Powell, 1955). This hypothesis has been proposed to interpret the widespread pelagic distribution of small *S. alutus* in offshore waters and as a possible explanation of adult rockfish which have been commonly noted in the stomachs of whales captured several hundred miles off the continental shelf. No actual specimens of *S. alutus* have, however, been verified or recorded as being captured from midwater areas off the continental slope.

Parasites

The parasite fauna of *S. alutus* has received little attention. Wilkes (1957) examined specimens of *S. alutus* caught off the mid-Oregon coast for presence and incidence of parasitic copepods. He found seven species, four of which were listed as probably new species. Species identified by Wilkes included:

Haemobaphes theragrae Yamaguti
Peniculus sp. (probable new species)
Chondracanthus pinguis Wilson
Chondracanthus sp. (probable new species)
Clavellopsis sp. (tentative identification and probable new species)
Colobomatus sp. (probable new species)

Mr. Wilkes has provided (by private communication) additional information he obtained but did not include in his thesis. The non-copepod species which he found in *S. alutus* included: three trematodes *Megalocotyle trituba. Prosorhynchus* sp., and *Lepidapedon* sp.; three cestodes *Bathriocephalus scorpii* and two distinct types of larval cestodes at the Plerocercoid stage; and at least two unidentified species of nematodes, one of which was a larval form. The regions of infestation included gill filaments, eye muscles, stomach, pyloric caeca, liver, intestine, visceral cavity, and gut wall.

Stern and Liston (1958) examined *S. alutus* fillets from fish caught over a wide range of the Northeast Pacific Ocean (Cape St. James, British Columbia, to Cape Blanco, Oregon). They report that *Prosorhynchus* sp. and *Porracaecum decipiens* (larval form) are common in the musculature of *S. alutus*.

Acknowledgments

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A.2

Racial Comparisons of Redfish from the Western North Atlantic and the Barents Sea

By
GEORGE F. KELLY, ALLAN M. BARKER, and GEORGE M. CLARKE
Bureau of Commercial Fisheries, Biological Laboratory, Woods Hole, Massachusetts, U.S.A.

Introduction

This paper reports the results of a review of meristic and morphometric characteristics that may be of value in redfish racial studies. The study was begun at the request of the Committee on Research and Statistics of the International Commission for the Northwest Atlantic Fisheries. It is not a comprehensive taxonomic study, but is rather a review of a large number of characteristics to serve as a background from which to select a few that might be useful in distinguishing races or populations of redfish for population dynamics studies and management purposes.

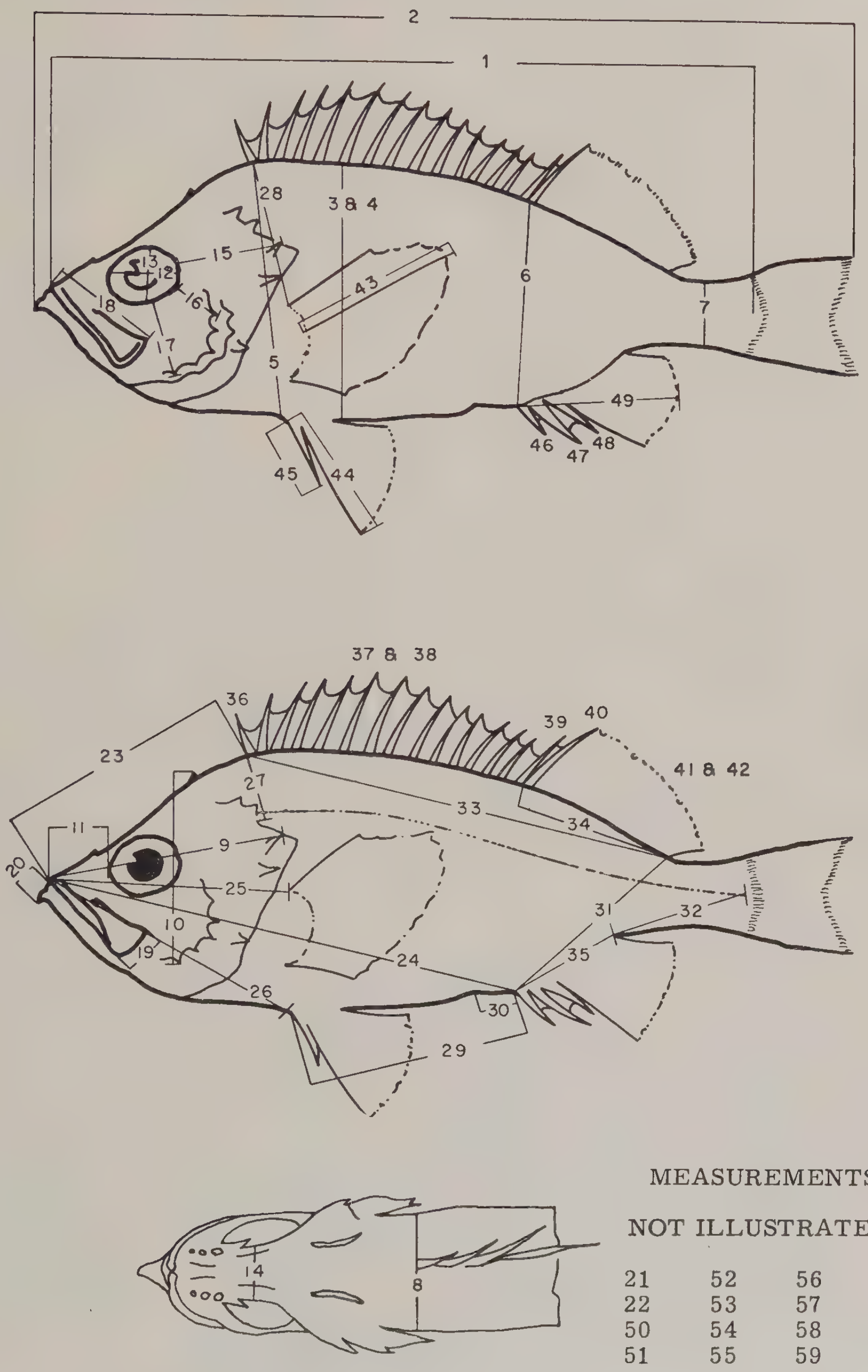
In recent years those working on the commercial fishery have felt some dissatisfaction with the present classification of the entire *Sebastes* group. In the opinion of some workers, the three forms of redfish referred to as *Sebastes marinus, S. mentella,* and *S. viviparus* were not sufficiently different to be classed as full species. It was felt that the genus had not been adequately sampled throughout its range and the normal racial variations were not known. Redfish from widely separated parts of the North Atlantic had never been compared critically.

The classification and nomenclature of the species or subspecies of North Atlantic *Sebastes* has been somewhat confused in the past. The following citations summarize chronologically the pertinent changes in classification of the three main types or species of redfish, *S. marinus, S. mentella* and *S. viviparus,* up to the present time:–

Perca marina (Linnaeus), 1758
Sebastes norvegicus (Cuvier and Valenciennes), 1829
Sebastes viviparus (Krøyer), 1844–45
Sebastes marinus (White), 1851
Sebastes fasciatus (Storer), 1854
Sebastes marinus viviparus (Jordan and Gilbert), 1883
Sebastes mentella (Travin), 1951
Sebastes marinus mentella (Andriiashev), 1954

Until very recently the names *Sebastes marinus* and *S. viviparus* included all of the known stocks of North Atlantic redfish. *S. marinus* was the name applied to the deep-water fish and *S. viviparus* was associated with the shallow-water form of the European coast. Differences in colour, size composition, and depth distribution of the deep-water fish from different geographical areas were known to exist. These were generally considered to be local variations of stocks that were sufficiently similar to fit within the broad limits of the early description of *Sebastes marinus.* At one time even *S. viviparus* was classified as a subspecies of *S. marinus.*

The sampling of new grounds that accompanied the expansion of the commercial fishery beween 1940 and 1946 disclosed redfish having greater variability in body form than had been previously recorded. Some of these were given descriptive common names before Travin (1951) described the large-eyed, long-chinned form as the new species *Sebastes mentella.* While his was the first step toward clarifying the status of the many *Sebastes* groups presently exploited by the modern fishery, Travin's naming of *S. mentella* posed the question whether each separable group of *Sebastes* qualified as a new species or simply as a local variation of *S. marinus.* Andriiashev (1954) questioned the validity of *S. mentella* as a full species, on the grounds that the variability of the characteristics used to describe it was not adequately known for the populations of redfish throughout the range in the North Atlantic. Andriiashev's view that differences of this magnitude could be at the subspecific level is shared by others. It is the purpose of this study to show the degree of variation of some of the characteristics that have been used in describing groups of redfish in the past. These results may direct future studies toward characteristics most likely to produce valid separations.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MEASUREMENTS

NOT ILLUSTRATED

21
22
50
51
52
53
54
55
56
57
58
59
60
61
62

Figure 1. Illustration of racial measurements used in the study (see App. I).

Methods

The three general areas: the Barents Sea, Iceland, and the Northwest Atlantic were initially established by the ICNAF committee as the sampling areas that were most likely to include the widest range of variation in racial characteristics. During 1958 samples of redfish were obtained from the Barents Sea in the east and from the Labrador coast, the Gulf of St. Lawrence, and the Gulf of Maine in the western Atlantic. Unfortunately it was not possible to obtain samples from Iceland in time for the material to be included in this study.

At the outset of the study a comprehensive list of 62 meristic and morphometric characteristics was compiled for consideration (Figure 1 and Appendix I). The definitions of terms and the methods of counting and measuring body parts follow the recommendations of Hubbs and Lagler (1958) as closely as possible.

Because of the limitations of time only a few of the measurements could be made on each fish. In order to concentrate on the *marinus-mentella* separation, the greatest number of measurements were made on fish from the areas displaying the greatest range in eye size, namely the Barents Sea and the Gulf of St. Lawrence. The location of the areas sampled, the list of measurements, and the number of fish measured from each area are summarized in Table 1. The results of earlier work on a selected few meristic and morphometric measurements are included for comparison with the more recent data. These include material from the Gulf of St. Lawrence, the Grand Banks, three areas on the Nova Scotian Banks, and six areas in the Gulf of Maine (Figure 2).

Table 1

Location and date of collection of samples and list of characteristics and number of fish measured

(See Appendix I and Figure 2)

Area	Sample number	Date collected	Latitude and longitude	Depth (fm)
Barents Sea	1	July 2, 1958	74° 26–29′ N– 16° 23′ E	195–220
	6	Sept. 9, 1958	74° 20–24′ N– 16° 24–26′ E	190–215
Labrador	3	Sept. 8, 1958	54° 00′ N– 54° 30′ W	135–150
	4	Aug. 30, 1958	54° 00′ N– 54° 30′ W	135–165
Eastport	7	July-Aug. 1958	44° 55′ N– 67° 00′ W	0–5
Gulf of St. Lawrence	2 {12 22	Aug. 14, 1958	50° 25′ N– 58° 40′ W	125–150

Characteristic number (See Appendix I)	Characteristic	Sample number 1	2	3	4	6	7
1	Standard length	93	198	103	36	48	50
2	Total length	93	198	103	36	48	50
5	Body depth, dorsal to ventral	93	198	103	36	48	50
6	Body depth, dorsal to anal	93	198	47	–	48	50
7	Depth of caudal peduncle	93	198	103	36	–	–
9	Head length	93	198	103	36	48	50
10	Parietal sp. to ant. preop. sp.	93	198	47	–	–	–
11	Snout length	93	198	47	–	48	50
12	Horizontal diam. of orbit	93	198	103	36	48	50
13	Vertical diam. of orbit	93	198	47	–	–	–
14	Interorbital width	93	198	103	36	48	50
15	Postorbital length	93	198	103	36	48	50
16	Orbit to dorsal preop. sp.	93	198	47	–	–	–
17	Orbit to anterior preop. sp.	93	198	47	–	–	–
18	Length of upper jaw	93	198	47	–	48	50
19	Width of posterior maxillary	93	198	47	–	48	50
20	Length of schnabel	93	198	103	36	48	50
23	Snout to dorsal fin	93	198	47	36	–	–
24	Snout to anal fin	93	198	47	–	–	–
25	Snout to pectoral fin	93	198	47	–	–	–
26	Snout to ventral fin	93	198	47	–	–	–
50	Dorsal fin count	93	99	47	–	48	50
51	Anal fin count	93	99	47	–	48	50
52	Pectoral fin count	93	99	47	–	48	50
54	Caudal fin count	93	99	47	–	48	50
58	No. of gill rakers, 1st arch	93	99	47	–	48	50

Results

There was a wide variation in the range of lengths of fish sampled from different areas (Figure 3). In some instances (e.g. Eastport and Labrador) the ranges of two groups did not overlap. This lack of consistency in size range had no effect on the meristic comparisons but was of importance in comparing the regressions of the morphometric characteristics. Regression lines of the small fish could not be extrapolated to the larger sizes with accuracy.

Meristic characteristics are summarized in Tables 2 to 5. Appendix II contains the unpublished redfish meristic notes of Å. Vedel Tåning, the only other material available for meristic comparisons of *Sebastes*. In the new data the number of dorsal spines ranges from thirteen to eighteen, the mode at fifteen in all areas. The modal number of soft rays in the dorsal fin is thirteen in the Gulf of Maine and Nova Scotian waters and fourteen in the areas to the north and east. The mean number of spines and rays in the dorsal fin shows a general increase from the Gulf of Maine north-

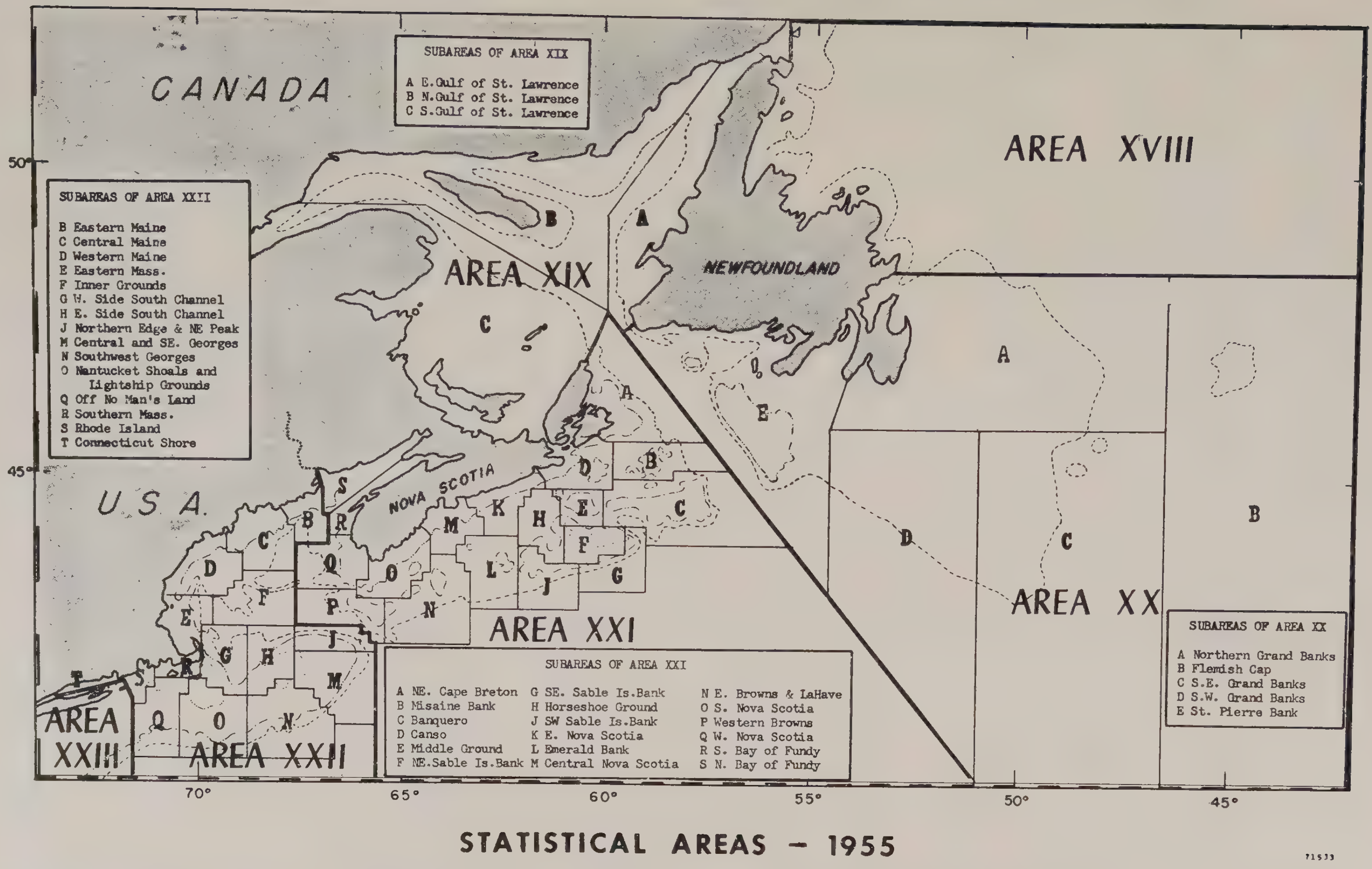
CANADA
U.S.A.
NEWFOUNDLAND
NOVA SCOTIA
AREA XVIII
AREA XIX
AREA XX
AREA XXI
AREA XXII
AREA XXIII
SUBAREAS OF AREA XIX
A E.Gulf of St. Lawrence
B N.Gulf of St. Lawrence
C S.Gulf of St. Lawrence
SUBAREAS OF AREA XXII
B Eastern Maine
C Central Maine
D Western Maine
E Eastern Mass.
F Inner Grounds
G W. Side South Channel
H E. Side South Channel
J Northern Edge & NE Peak
M Central and SE. Georges
N Southwest Georges
O Nantucket Shoals and Lightship Grounds
Q Off No Man's Land
R Southern Mass.
S Rhode Island
T Connecticut Shore
SUBAREAS OF AREA XXI
A NE. Cape Breton
B Misaine Bank
C Banquero
D Canso
E Middle Ground
F NE.Sable Is.Bank
G SE. Sable Is.Bank
H Horseshoe Ground
J SW Sable Is.Bank
K E. Nova Scotia
L Emerald Bank
M Central Nova Scotia
N E. Browns & LaHave
O S. Nova Scotia
P Western Browns
Q W. Nova Scotia
R S. Bay of Fundy
S N. Bay of Fundy
SUBAREAS OF AREA XX
A Northern Grand Banks
B Flemish Cap
C S.E. Grand Banks
D S.W. Grand Banks
E St. Pierre Bank
50°
45°
70°
65°
60°
55°
50°
45°
STATISTICAL AREAS – 1955
71533

Figure 2. Statistical subareas of the Northwest Atlantic Ocean. (U.S. Fish and Wildlife Service designation based on boundaries established by North American Council on Fishery Investigations.)

Area	Sample	Number of Specimens
Barents Sea	#1	93
	#6	48
Gulf of St. Lawrence	#2 { 12 22	198
Labrador	#3	103
	#4	36
Eastport	#7	50
Gulf of St. Lawrence XIX A	From earlier studies (1956)	424
Grand Banks XX C	"	160
D	"	212
Nova Scotia Banks XXI C	"	100
H	"	175
O	"	148
Gulf of Maine XXII C	"	129
D	"	181
E	"	802
F	"	172
G	"	159
H	"	126

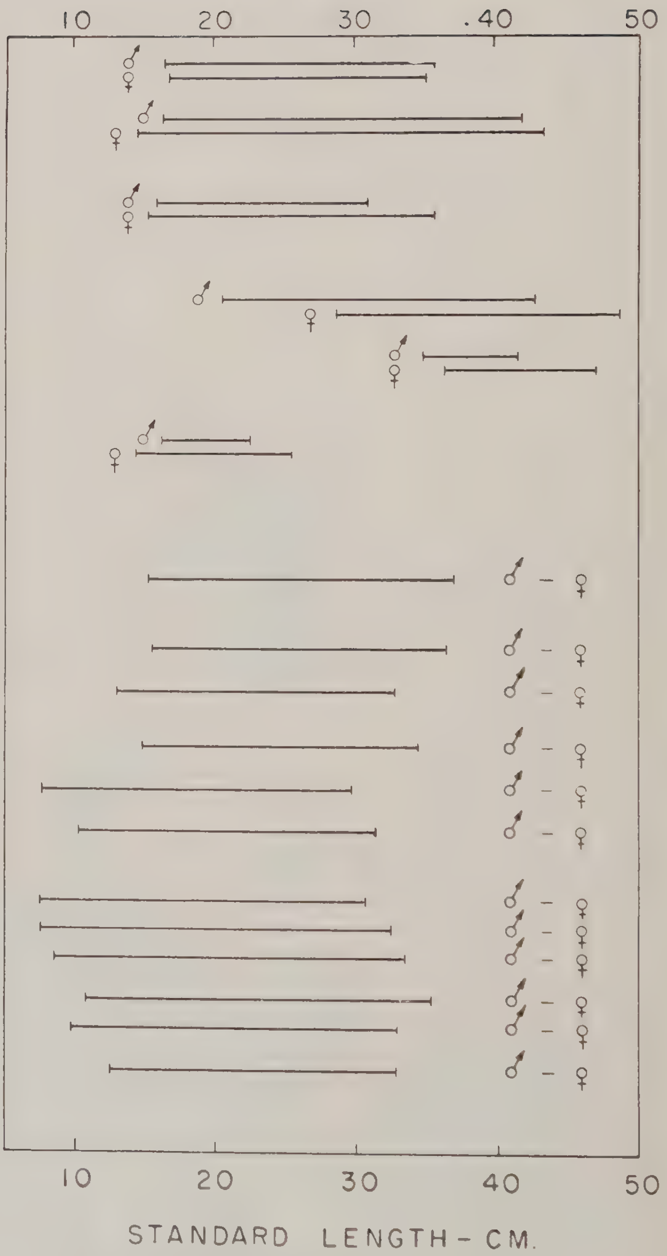

Figure 3. Range of standard lengths of specimens from different areas.

Table 2
Number of spines and soft rays in the dorsal fin of redfish from different areas
(see Figure 1)

Area	XIII		XIV						XV				XVI					XVIII	
SPINES / SOFT RAYS	13	14	11	12	13	14	15	16	12	13	14	15	12	13	14	15	16	13	Total
Barents Sea																			
Sample 1	–	–	–	–	–	–	1	–	1	29	*45*	17	–	–	–	–	–	–	93
Sample 2	–	–	–	–	–	1	–	1	–	1	15	*25*	–	–	1	–	1	–	45
Area XVII (Labrador Coast)	–	–	–	–	–	–	–	–	–	21	*24*	1	1	–	–	–	–	–	47
Area XIX (Gulf of St. Lawrence)																			
Subarea A1	–	–	–	–	–	–	6	2	1	6	*54*	26	–	1	2	1	–	–	99
Subarea A2	–	–	–	–	–	1	3	–	–	34	*46*	14	–	1	–	–	–	–	99
Subarea C	–	–	–	–	–	–	1	–	–	6	*13*	1	–	–	–	–	–	–	21
Area XX (Grand Bank)																			
Subarea C	–	–	–	–	1	–	–	–	–	3	*12*	1	–	3	–	–	–	–	20
Subarea E	–	–	–	–	–	1	1	–	–	8	*9*	1	–	–	–	–	–	–	20
Area XXI (Nova Scotia Banks)																			
Subarea C	1	–	–	–	–	2	–	–	1	*6*	*6*	2	–	–	–	2	–	–	20
Subarea O	–	–	–	–	–	–	–	–	1	*14*	11	–	–	–	–	–	–	–	26
Subarea N	–	–	1	–	–	1	–	–	–	*38*	30	2	1	4	–	–	–	–	77
Area XXII (Gulf of Maine)																			
Eastport	–	–	–	–	–	–	–	–	11	*70*	22	–	2	1	–	–	–	–	106
Subarea C	–	–	–	–	–	–	–	–	–	*17*	4	–	–	–	–	–	–	–	21
Subarea D	–	1	–	–	–	3	1	–	2	*16*	13	–	–	1	–	–	–	–	37
Subarea E	–	–	–	–	1	2	–	–	–	*30*	24	2	–	1	1	–	–	–	61
Subarea G	–	–	–	–	–	1	–	–	–	*10*	8	–	–	1	–	–	–	–	20
Subarea M	–	–	–	–	–	2	–	–	–	*42*	32	–	–	1	1	–	–	1	79
Total	1	1	1	–	2	14	13	3	17	351	*368*	92	4	14	5	3	1	1	891

ward to the Barents Sea, suggesting a possible clinal distribution of the characteristic in the whole population complex (Table 3). All of these values fall between the highest and lowest values shown by Tåning for *marinus* and *viviparus* respectively.

The number of spines and rays in the anal fin and pectoral fin display variations within each sample and area, but there is no apparent pattern of consistent differences between areas. There is perhaps the suggestion of an increasing gradient from south to north. Tåning's values for *viviparus* are consistently at the lower end of the range of values for the other samples.

The number of gill rakers ranges from 30 to 40 in the new samples, compared with 30 to 41 in Tåning's *marinus-viviparus* data. Sample modes range between 34 and 36 for *marinus* in all areas, compared with 38 for *viviparus*. The mean number of rakers suggests a decreasing gradient from south to north, the reverse of the distribution indicated by the other meristics.

Table 3
Dorsal fin counts

Area	Number of rays 25	26	27	28	29	30	31	32	Total no. of fish	Mean no. of rays
Barents Sea	–	–	1	31	*61*	44	–	1	138	29·12
Area XVII Labrador	–	–	–	22	*24*	1	–	–	47	28·55
Area XIX Gulf of St.Lawrence	–	–	1	47	*125*	45	1	–	219	29·00
Area XX Grand Banks	–	–	1	12	*25*	2	–	–	40	28·70
Area XXI Nova Scotia	1	1	2	*62*	51	4	2	–	123	28·47
Area XXII Gulf of Maine	–	–	15	*195*	109	4	1	–	324	28·32
Total number of rays	1	1	20	369	*395*	100	4	1	891	

Table 4

Number of rays in anal fin and pectoral fin of redfish from different areas

(see Figure 1)

Area	Number of rays Anal fin					Total number of fish	Mean number of rays	Number of rays Pectoral fin			Total number of fish	Mean number of rays
	9	10	11	12	13			18	19	20		
Barents Sea	–	33	*74*	30	1	138	10·99	9	*115*	13	137	19·03
Area XVII Labrador Coast	3	*32*	12	–	–	47	10·19	2	*35*	9	46	19·15
Area XIX Gulf of St Lawrence												
A	1	61	*100*	36	1	199	10·87	11	*150*	35	196	19·12
C	–	–	*21*	–	–	21	11·00	–	*16*	5	21	19·24
Area XX Grand Banks												
C	1	*17*	2	–	–	20	10·05	3	*15*	2	20	18·95
E	–	*15*	5	–	–	20	10·25	–	*19*	1	20	19·05
Area XXI Nova Scotia Banks												
C	–	*9*	7	4	–	20	10·75	2	*15*	3	20	19·05
N	1	*66*	10	–	–	77	10·12	4	*68*	5	77	19·01
O	–	*19*	7	–	–	26	10·27	4	*20*	2	26	18·92
Area XXII Gulf of Maine												
B	22	*80*	4	–	–	106	9·83	35	*71*	–	106	18·67
C	1	*20*	–	–	–	21	9·95	4	*17*	–	21	18·81
D	–	–	–	–	–	–	–	6	*30*	1	37	18·86
E	2	*53*	6	–	–	61	10·17	17	*44*	–	61	18·72
G	–	*16*	4	–	–	20	10·20	4	*15*	1	20	18·85
M	–	*59*	20	–	–	79	10·25	2	*69*	8	79	19·08
Total	31	*480*	272	70	2	855	10·45	103	*699*	85	887	18·98

Table 5

Number of gill rakers on first gill arch of redfish from different areas

(see Figure 1)

Area	Number of rakers											Total number of fish	Mean number of rakers	
	30	31	32	33	34	35	36	37	38	39	40			
Barents Sea	–	–	6	37	*55*	30	8	1	–	–	–	137		34·00
Area XVII Labrador Coast	–	–	2	9	*17*	15	4	–	–	–	–	47		34·21
Area XIX Gulf of St. Lawrence														
A	–	–	1	11	50	54	*57*	20	4	–	1	198	34·81	34·64
C	1	–	3	11	*20*	9	4	–	–	–	–	48	33·92	
Area XXI Nova Scotia														
N	–	–	–	5	6	*34*	17	12	2	1	–	77		35·45
Area XXII Gulf of Maine														
B	–	–	–	3	21	*37*	17	3	1	–	–	82	34·84	34·82
C	–	–	1	–	6	*8*	4	1	–	–	–	20	34·80	
D	–	–	–	–	1	3	*6*	–	–	–	–	10		
M	–	–	–	6	4	*11*	3	–	–	–	–	24		
Total	1	–	13	82	180	*201*	120	37	7	1	1	643		

ning's *viviparus* is obviously different from all other nples in gill raker number, despite its similarity to Gulf of Maine fish in dorsal, anal, and pectoral fin ınt.

Tåning's count of the number of scale pouches below lateral line (Appendix I) is undoubtedly the best aracteristic for separating *viviparus* from the other lfish groups. Whether it is of value in *marinus-ntella* separation is not known. The count is best ne on fresh specimens. Since most of the available terial for the present study was preserved in for-ldehyde, this count was not taken.

The quantity of morphometric data at hand is too at for presentation in this paper. Regressions were nputed for the relationship of each morphometric racteristic on standard length. Regression lines for same characteristic from each sample were com-ed in order to classify the degree of variation. Three egories were established and were approximately ined in terms of regression slope and standard iation as follows:–

Group A – Greatest variation – When one or more ression lines did not intercept all other regression s within the range of the data, and when the values he means (plus or minus 2 standard deviations) of or more samples did not overlap each other.

Group B – Medium variation – When one regression did not intercept all others at or near their point convergence, and when the values of the means is or minus 2 standard deviations) of two or more ples showed little overlap.

roup C – Least variation – When all regression s converged at or near a common intercept point, when each value of the mean (plus or minus 2 dard deviations) overlapped all others.

nder these terms, the characteristics arranged nselves into the groups as follows:–

roup A – Greatest variation
12 Horizontal diameter of orbit/Standard length
13 Vertical diameter of orbit/Standard length
5 Body depth (dorsal fin to ventral fin)/ Standard length
26 Snout to ventral fin/Standard length
24 Snout to anal fin/Standard length

roup B – Medium variation
20 Schnabel length/Standard length
15 Postorbital length/Standard length
14 Interorbital width/Standard length
6 Body depth (dorsal fin to anal fin)/ Standard length
23 Snout to dorsal fin/Standard length
25 Snout to pectoral fin/Standard length
16 Orbit to most dorsal preopercular spine/ Standard length
10 Parietal spine to most anterior preop. spine/ Standard length

Group C – Least variation
9 Head length/Standard length
11 Snout length/Standard length
18 Length of upper jaw/Standard length
7 Caudal peduncle depth/Standard length
19 Postmaxillary width/Standard length
17 Orbit to most anterior preopercular spine/ Standard length

Examples from each category are presented in Figure 4. The vertical scale in the figure is exaggerated to show the small differences in the lines which would otherwise be obscured. The means and standard deviations were computed for each regression, using a standard length of 250 mm, for all samples. This method of presentation reduces the bias caused by inadequate sampling and permits comparison of the degree of overlap of each characteristic between samples.

Diameter of orbit appears to be the morphometric characteristic showing the most consistent pattern of variation and is the most promising for separating groups of *Sebastes*. Although Travin (1951) associated large eye size with long schnabel, the regressions of schnabel on standard length indicate that it is a less reliable characteristic than eye size for separating groups.

The Gulf of St. Lawrence sample was separated into two groups on the basis of eye size in order to compare the variation of other characteristics in large-eyed and small-eyed fish. There was a natural separation in that sample at an orbit diameter of 35·0 mm. The small-eyed fish were called sample No. 12 and the large-eyed fish sample No. 22. Sample No. 22 contained, on the whole, larger fish and in most of the regression comparisons it stands out as widely different from all other samples, as would be expected in a selected sample.

A comparison was made of the large-eyed and small-eyed (Gulf of St. Lawrence) fish to determine whether differences in some of the meristic characteristics were associated with eye size. The average number of gill rakers and number of dorsal spines and rays were computed for both groups. The mean values are:–

Sample No.	Number of fish	Mean standard length (mm)	Mean diameter of orbit (mm)
12	42	275·3	30·7 ratio ·111
22	49	304·3	40·9 ·134

Sample No.	Number of fish	Mean number of gill rakers	Mean number of dorsal rays
12	42	34·74	29·17
22	49	34·78	29·30

The extremely small difference in mean value of the meristics between samples of fish differing so greatly in mean orbit diameter indicates that variations in orbit size are not related to variations in meristic numbers.

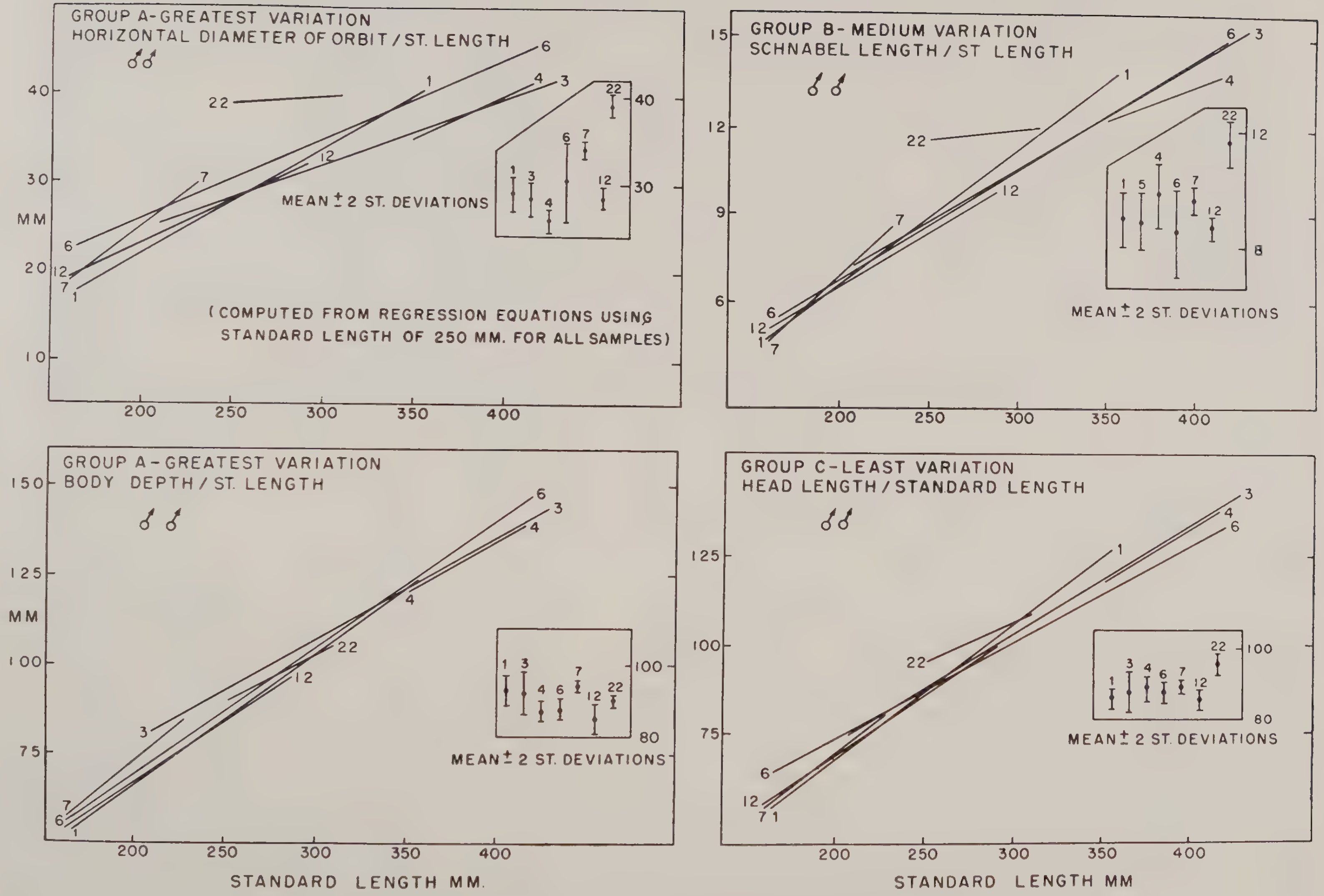

Figure 4. Examples of morphometric regressions illustrating the three categories of variation.

Table 6

Means and confidence limits (± 2 standard deviations) of measurements for males, computed with standard length equal to 250 mm

Measurement / Sample Nos.	Barents Sea 1	6	Labrador 3	4	Eastport 7	St. Lawrence 12	22
Group A							
Horizontal diameter of orbit	28·9 ± 4·4	30·5 ± 8·2	28·4 ± 4·4	25·8 ± 2·8	33·9 ± 2·2	28·4 ± 2·2	39·0 ± 3·0
Vertical diameter of orbit	28·0 ± 4·2	–	26·9 ± 3·2	–	–	27·3 ± 2·2	36·9 ± 3·2
Body depth (dorsal to ventral fin)	93·5 ± 8·1	86·8 ± 7·0	91·7 ± 14·8	86·5 ± 7·2	94·7 ± 3·7	83·9 ± 7·6	88·6 ± 7·4
Snout to ventral fin	101·1 ± 6·6	–	96·8 ± 7·4	–	–	94·8 ± 7·2	96·3 ± 7·2
Snout to anal fin	170·0 ± 8·2	–	178·6 ± 13·0	–	–	173·0 ± 11·8	175·7 ± 11·6
Group B							
Body depth (d. to a. fin)	65·8 ± 5·0	69·7 ± 10·4	69·1 ± 10·2	–	68·0 ± 5·4	65·3 ± 5·4	62·3 ± 6·2
Snout to dorsal fin	89·3 ± 8·8	–	92·1 ± 9·8	86·3 ± 7·0	–	87·1 ± 6·0	100·2 ± 7·0
Snout to pectoral fin	86·7 ± 5·6	–	84·5 ± 7·0	–	–	83·6 ± 5·6	87·3 ± 6·6
Schnabel length	9·0 ± 1·8	8·4 ± 3·4	8·9 ± 2·0	9·9 ± 1·8	9·7 ± 1·0	8·6 ± 1·0	11·5 ± 1·6
Interorbital width	18·5 ± 2·0	18·6 ± 2·2	19·8 ± 3·6	18·2 ± 3·0	18·0 ± 1·2	17·6 ± 1·6	18·5 ± 4·2
Postorbital length	37·8 ± 3·0	36·2 ± 3·8	38·9 ± 6·4	41·0 ± 4·0	36·9 ± 1·4	39·1 ± 3·2	39·0 ± 4·0
Orbit to dorsal preop. spine	20·4 ± 2·6	–	20·7 ± 3·8	–	–	20·9 ± 2·2	17·8 ± 2·8
Parietal sp. to dorsal preop. spine	63·6 ± 4·0	–	64·7 ± 6·2	–	–	62·9 ± 4·0	72·2 ± 3·2
Group C							
Orbit to anterior preop. spine	25·7 ± 2·0	–	26·1 ± 3·0	–	–	25·9 ± 2·2	25·5 ± 2·6
Head length	86·1 ± 5·0	87·5 ± 4·6	88·0 ± 11·2	88·5 ± 5·2	89·2 ± 3·0	86·0 ± 4·4	95·6 ± 5·6
Snout length	21·5 ± 2·2	–	21·7 ± 3·4	–	19·7 ± 1·8	20·1 ± 2·4	20·4 ± 2·4
Upper jaw length	42·2 ± 2·6	42·4 ± 3·8	41·8 ± 3·2	–	42·2 ± 1·2	41·4 ± 2·6	43·5 ± 3·2
Postmaxillary width	14·6 ± 2·6	14·7 ± 2·2	15·6 ± 2·2	–	16·5 ± 1·4	14·3 ± 1·6	14·9 ± 1·6
Caudal peduncle depth	21·4 ± 2·4	–	25·1 ± 4·6	23·6 ± 4·0	–	22·8 ± 2·2	23·4 ± 2·4

Since eye size is the characteristic that consistently shows the greatest variations in relation to other body dimensions, an attempt has been made to compare the ratio of diameter of orbit/standard length for all samples available with sexes separate. The ratios range from 0·085 to 0·155 with a rather broad range of values in each sample (Figure 5). The values were smoothed by threes and plotted as percentages. It is interesting to note that in most areas a unimodal or trimodal distribution occurs, rather than a simple bimodal distribution that should occur if a clear separation of *marinus* and *mentella* were possible. The Labrador fish have an orbit/length ratio distinctly different from all other groups. The highest ratio is present in the Gulf of St. Lawrence and on the Nova Scotian banks, values well above the Barents Sea mode. In fact, the major mode in the Barents Sea distribution coincides with the lowest of three ratio modes present in the Gulf of St. Lawrence. Whatever the number of orbit/length ratio groups represented in the samples, when they are added together the total sample distribution tends toward a normal distribution. While this ratio comparison is admittedly a rough approximation, perhaps uniform sampling across the North Atlantic will disclose a normal distribution of eye size for the whole *Sebastes* population complex.

Discussion

From the data presented in this study it would be difficult to determine whether the forms of *Sebastes* represented in the samples are genetically or environmentally controlled. It is clear that relative orbit diameter is a variable characteristic in all groups of *Sebastes* sampled. In most comparisons of eye size it is assumed that the orbit diameter/standard length ratio is genetically fixed and is constant throughout the life of the fish. Some of the data suggest that this may not be true. The mystery of the origin of the large-eyed fish in the Gulf of St. Lawrence is a case in point. Random samples of the commercial catch show a constant ratio in fish up to a total length of about 30 cm. From 30 cm upward, a large-eyed group of fish is present that is not represented at smaller lengths. This condition could be the result of the smaller fish of the large-eyed group being unavailable to the otter trawl for a period of years because of sustained pelagic existence. However, it could also be the result of adverse ecological conditions such as inadequate food supply, invasion of parasites or disease resulting in detrimental effects to the well-being of the fish. Emaciation of the larger fish might lead to a change in the orbit diameter/standard length ratio.

Although it is impossible to enumerate the racial

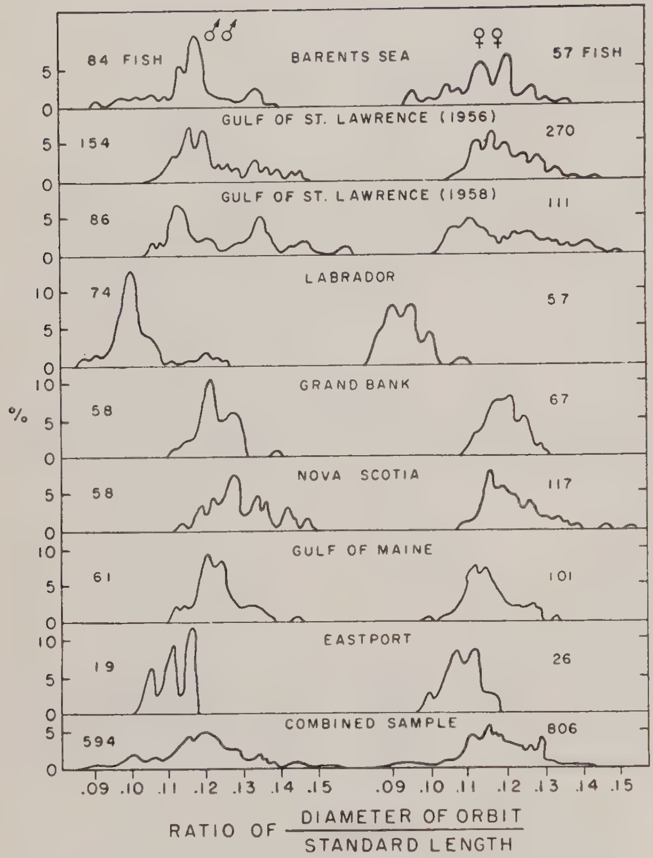

Figure 5. Percentage composition of diameter of orbit/standard length ratio by area, sexes separate.

characteristics of *Sebastes* that are genetically or environmentally influenced, now that meristic and morphometric data have been studied in detail and comparatively small differences across the whole range of *Sebastes* have been found, other factors must be scrutinized in the same detail. It is necessary to establish the validity of previously reported relationships between racial characteristics and environmental conditions before those which are the diagnostic characteristics can be determined. Some attributes that have been linked with ecological factors may in fact be largely independent of environment. The present interpretation of the *Sebastes* racial structure is influenced by these environmental relationships which may be valid in local populations but which do not apply to the whole *Sebastes* complex. In the earlier racial separations of *S. marinus, S. mentella,* and *S. viviparus,* characteristics such as comparative eye size, growth rate, time of spawning, and depth distribution were cited as evidence of the separateness of groups that suggested species differences. Each of these could be genetically or environmentally related and could represent differences between species or merely local racial variations.

Perhaps some basic ecological relationships can be established if the same problems in all parts of the *Sebastes* range are considered. The following questions are submitted for the consideration of investigators in future redfish studies:–

1. Is there good evidence indicating that two groups of *Sebastes* spawn in the same area at widely different times?
2. Has a positive relationship between increasing orbit diameter/standard length ratio and greater water depth been shown for *Sebastes*?
3. What is the effect of fast or slow growth on body proportions of fish from the same population? Does early or late maturity result in measurable differences in body form?
4. Is there evidence from any species that an extended pelagic period of life could result in body form different from that of the bottom-dwelling stocks of the same species?
5. Is there evidence from any species of changes in body proportions caused by changes in nutrition or the invasion of parasites or disease?

Conclusions

This review of meristic and morphometric characteristics has served to broaden the view of the *Sebastes* racial variations, and has narrowed the range of characteristics to be investigated. More widespread sampling of the whole *Sebastes* group is necessary. The measurement of a few selected meristic and morphometric characteristics in conjunction with studies of serology, genetics, and incidence of parasites and disease in key areas of the range should provide satisfactory answers to the present problems of *Sebastes* classification.

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APPENDIX I

Definitions of Redfish Racial Measurements

1. Standard length. The distance from the most anterior part of the snout or upper lip at the midline to the caudal base.

2. Total length. The greatest dimension between the most anteriorly projecting part of the head (the tip of the lower jaw with the mouth closed) and the farthest tip of the caudal fin when the rays are spread normally.

3. Greatest depth of body. The greatest vertical dimension of the body exclusive of fins.

4. The number of the dorsal spine beneath which the body is most deep.

5. Body depth at origin of dorsal fin to origin of ventral fin. The least dimension between the base of the first dorsal spine and base of the ventral spine.

6. Body depth at base of last dorsal spine to base of first anal spine. Distance from base of last dorsal spine (i.e. the spine just ahead of the soft rays) to the base (anterior edge) of the first anal spine.

7. Least depth of caudal peduncle.

8. Width of body between uppermost points of gill openings. The body width measured at the points where the gill flap joins the body.

9. Length of head. The distance from the most anterior part of the snout or upper lip at the midline to the posterior point of the opercular spine.

10. Tip of last parietal spine to tip of most anterior preopercular spine (a measure of head depth).

11. Length of snout. The least dimension between most anterior point of upper jaw at the midline and the nearest point on the orbit.

12. Diameter of orbit – horizontal.

13. Diameter of orbit – vertical.

14. Interorbital width. Least bony interorbital width.

15. Postorbital length. Least dimension between the tip of the spine on gill flap to the nearest point on the orbit.

16. Distance between orbit and tip of most dorsal preopercular spine.

17. Orbit to most anterior preopercular spine. Least distance between tip of anterior preopercular spine and nearest point on orbit.

18. Length of upper jaw. Greatest dimension between tip of upper jaw, at the midline, to the posterior end of the maxillary.

19. Greatest width of posterior end of maxillary.

20. Length of "schnabel". The dimension made by placing one point of the dividers or the knife-edge of a caliper on the anterior midline of the upper surface of the lower jaw between the teeth; the other divider tip or caliper edge on the most distant point of the mandibular projection or schnabel.

21. Length of longest gill raker. Distance from base of gill raker, on the side at which it forms an acute angle with the arch, to the tip of the raker.

22. Number of longest raker. The first raker which has both roots in the lower limb is counted as number one.

23. Snout to origin of dorsal fin. Anterior midpoint of tip of snout to base of first dorsal spine.

24. Snout to origin of anal fin. Anterior midpoint of snout to base of first anal spine.

25. Snout to insertion of pectoral fin. Anterior midpoint of snout to base of uppermost pectoral ray.

26. Snout to insertion of ventral fin. Anterior midpoint of snout to base of ventral spine.

27. Origin of dorsal fin to uppermost point of gill opening.

28. Origin of dorsal fin to insertion of pectoral fin. Distance from base of first dorsal spine to base of uppermost pectoral ray.

29. Origin of ventral fin to origin of anal fin. Distance between bases of ventral spine and first anal spine.

30. Posterior edge of anus to origin of anal fin (i.e. base of first anal spine).

31. Origin of anal fin to base of last dorsal ray. Distance from base of first anal spine to the rear edge of the base of the last dorsal ray.

32. Length of caudal peduncle. Distance between rear edge of base of last anal ray and the hidden base of the midcaudal ray.

33. Length of base of dorsal fin (spinous and soft). Distance between origin of first spine and rear edge of base of the last soft ray (exclusive of the membrane which connects the proximal third or quarter of this ray to the dorsal midline of the body).

34. Length of base of soft dorsal fin (including its spine). Distance from base of last spine in the dorsal fin, which is the first spine in the second dorsal fin, to the rear edge of the base of the last dorsal ray.

35. Length of base of anal fin. Distance from base of first spine to rear edge of the base of the last ray (exclusive of the membrane which follows the last ray).

36. Length of first dorsal spine.

37. Length of longest dorsal spine.

38. Number of longest dorsal spine.

39. Length of penultimate dorsal spine.

40. Length of last dorsal spine.

41. Length of longest dorsal ray.

42. Number of longest dorsal ray.

43. Length of longest ray of pectoral fin. Distance between the base and the tip of the longest ray (used in preference to a pectoral length measured from upper point of fin insertion because the pectoral length so measured varies with the position of the fin).

44. Length of ventral fin. Distance between base of ventral spine and tip of longest ray, with the fin laid back against the belly.

45. Length of ventral (fin) spine.

46. Length of first anal spine.

47. Length of second anal spine. (It is usually necessary to remove some of the skin which covers the bases of these spines.)

48. Length of third anal spine.

49. Depressed length of anal fin. Distance from base of first anal spine to the farthermost point when the fin is flattened down.

50. Dorsal fin count: e.g. XV, 13, indicating 15 spines in first dorsal and 13 rays in second or soft dorsal.

51. Anal fin count: e.g. III, 7.

52. Pectoral fin count: e.g. 4,6,9=19. 4 uppermost pectoral rays unbranched followed by 6 branched and 9 lower unbranched rays.

53. Ventral fin count: e.g. I, 5. (This count will doubtless prove to be worthless.)

54. Caudal fin count: e.g. I-11-I. Eleven branched rays flanked above and below by one long and major but unbranched ray.

55. Vertebrae count – total including hypural.

56. Precaudal vertebrae count.

57. Caudal vertebrae count – including hypural.

58. Number of gill rakers on first arch, e.g. 10+1+24. Ten on upper arch, twenty-four on the lower, and one which straddles the two.

59. Number of lateral line pores.

60. Number of scale pouches below lateral line; upper end of gill opening to base of midcaudal ray. (Remove scales with forceps or by scraping with blade.)

61. Number of scale rows between origin of anal fin and lateral line, counting upward and forward.

62. Number of scale rows around narrowest part of caudal peduncle.

Prepared by:

G. F. Kelly
G. W. Mead
U.S. Fish and Wildlife Service
March 21, 1958

APPENDIX II

Summary of Meristic Characteristics of *Sebastes* (Adult)

(From unpublished notes of Å. Vedel Tåning. Data given to senior author by the late Dr. Tåning.)

Scale pouches below lateral line				
Number	*marinus*[1]	*fasciatus*[2]	Number	*viviparus*
67	–	1	49	–
66	–	1	48	–
65	–	3	47	–
64	–	4	46	–
63	1	11	45	3
62	2	11	44	9
61	3	11	43	10
60	6	13	42	20
59	5	12	41	30
58	7	14	40	31
57	6	1	39	44
56	6	1	38	31
55	7	–	37	29
54	5	–	36	25
53	1	–	35	5
52	1	–	34	1
51				a238 = 39·27
50				
	a*50 = 57·38	a83 = 60·47		

[1] *S. marinus*
[2] American form; "fasciatus" should be replaced by new name(?).
* a = average.

Number of gill rakers (Gi)

Number	*marinus*	*fasciatus*	*viviparus*
41	–	–	1
40	–	–	5
39	1	1	14
38	–	2	17
37	1	7	15
36	2	10	8
35	3	14	1
34	2	9	–
33	1	3	–
32	1	2	–
31	–	1	–
30	–	1	–
	a11 = 35·09	a50 = 35·08	a61 = 37·89

Number of rays in caudal fin

Number	*marinus*	*fasciatus*	*viviparus*
41	3		–
40	4		–
39	22		1
38	7		10
37	2		131
36	–		69
35	–		45
34	–		3
33	–		–
32	–		–
31	–		–
30	–		–
	a38 = 38·97	?	a259 = 36·40

Number of spines and rays in dorsal fin ($D_1 + D_2$)

Number	*marinus*	*fasciatus*	*viviparus*	*mentella*
31	4	1	–	–
30	17	3	3	–
29	14	27	83	–
28	3	19	165	–
27	–	–	9	–
26	–	1	–	–
	a38 = 29·58 (15 + 14 – *15*)	a51 = 28·69 (15 + *13* – 14)	a260 = 28·31 (15 + *13* – 14)	(15 + 14 – *15*)

Number of spines and rays in anal fin (3+x)

Number	*marinus*	*fasciatus*	*viviparus*	*mentella*
13	1	–	–	–
12	18	–	–	–
11	16	20	5	–
10	3	30	215	–
9	–	1	41	–
	a38 = 11·45	a51 = 10·37	a261 = 9·86	(3 + 8 – *9*)

Number of rays in pectoral fin

Number	*marinus*	*fasciatus*	*viviparus*	*mentella*
20	5	2	–	–
19	32	42	15	–
18	1	14	233	–
17	–	1	13	–
	a38 = 19·11	a59 = 18·76	a261 = 18·01	(18 – 19)

Total number of vertebrae

Number	*marinus*	*fasciatus*	*viviparus*	*mentella*[1]
32	1	–	–	–
31	80	9	3	10
30	16	23	116	76
29	–	–	2	3
	a97 = 30·85 (Kotthaus: 30·9)	a32 = 30·38	a121 = 30·01	a89 = 30·08

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[1] *S. mentella* Travin 1951 = "Tiefenbarsch".

A. 3

Contributions to the Race Problem in Redfish

By
ADOLF KOTTHAUS
Biologische Anstalt Helgoland, Bremerhaven

Abstract

Introduction

Lundbeck (1940) was the first to call attention to the fact that the North Atlantic redfish population does not form a uniform stock but that at least two different types of redfish may be distinguished, in addition to the small species *Sebastes viviparus* Kr. 1844. He separated first the common redfish, known from literature as *Sebastes marinus* (L.), and secondly a deep sea type differing in many respects from the first and which had been previously found in the Bear Island region and on the Iceland-Faroe Ridge ('Rosengarten'). The question was left open whether this deep sea redfish (called in German "Schnabelbarsch" = the beaked perch) was a new species or not. Subsequently this deep sea redfish was found in the deeper layers of all regions of the Northern Atlantic. Kotthaus (1950 b) described it from the Lofoten area and compared it with the common redfish, but he also could not decide about its taxonomic status, since the amount of material was rather small, and he therefore merely referred to two different "forms" of the fish. Travin (1951) described the deep sea redfish of the Barents Sea and the Bear Island region as a new species and called it *Sebastes mentella.* Andriascheff (1954), (following Berg) restricted *Sebastes mentella* to the status of an infra-species, because he found the differences at that time not clear enough to justify it as a separate species. From this there appear clearly some of the difficulties met with in the race problem in redfish. The author, therefore, preferred to speak of different "types" of fish until a definitive solution is possible.

Since publication of his paper dealing with the race problem in redfish, the author has investigated many redfish samples from all parts of the North Atlantic between the Barents Sea and Labrador. Many observations have been made about the occurrence of the different redfish types. From these observations it was found that the race problem was much more complicated than ever supposed. Especially it was remarkable that fish were often found (sometimes in considerable numbers) which could be looked upon neither as *marinus* nor as *mentella* types, for they possessed characters of both types in a varying manner. Some of the fish resembled more the one type, some more the other, and some took a truly intermediate position between the two, so that it was possible to arrange a series of fish, at the one end of which was the *marinus* and at the other end the *mentella* type. Between them were found all kinds of transition links. These latter were included in the group of "intermediate types", which is therefore a very heterogeneous one. It is interesting that all small fish up to about 20 cm total length have intermediate characters. On the other hand no *mentella* type fish were found smaller than about 30 cm or larger than 57 cm total length.

There is a fourth group of fish which must be mentioned—the so-called "Riesen" or "giants". These giant fish are caught mostly in the deeper layers where usually only the *mentella* type occurs. They are mostly above 60 cm in length and are, therefore, well separated from the normal range of *marinus* and *mentella* length curves. On the whole, they resemble the *marinus* type, but some noticeable differences exist in both proportions, e.g. in the average number of gill rakers, and in the internal structure of the otoliths, and it is therefore doubtful that these giants are merely large specimens of the *marinus* type.

The question arises, therefore, what is the taxonomic status of these different types? Are they true species, are they subspecies, infra-species, or ecotypes? This question may only be solved by a taxonomic study of a very large material, comprising fish from all parts of the redfish area.

By investigating a considerable material during the last two years the author has tried to make a contribution towards the solution of this problem.

Material and Methods

The material comprised a total of 1,512 redfish, including 96 specimens of the species *Sebastes viviparus;* 768 fish were of the *marinus* type (including a small number of giants), 311 fish were of the *mentella* type, and 337 of the intermediate types. The fish were collected on two cruises of the R.V. "Anton Dohrn", one in March/April, 1958 (East Greenland, Iceland-Greenland Ridge, and West Iceland) and the other in April/May, 1959 (South and East Iceland, Iceland-Faroe Ridge, north-east of the Faroe Islands, and Rockall Bank). Material from West Greenland was collected by the Greenland Fisheries Investigations and placed at the author's disposal.

The studies comprised: (a) body proportion measurements (1,412 fish), (b) fin-ray counts (1,502 fish), (c) vertebrae counts (1,325 fish), and (d) gill raker counts (247 fish).

From each single fish twenty body measurements were made and the following were used for comparison: (1) standard length, (2) head length, (3) length of snout (pre-orbital space), (4) horizontal diameter of orbit, (5) inter-orbital ridge, (6) length of the upper jaw, (7) length of "Schnabel" (=hook of the dentale), (8) height of body, (9) pre-dorsal length, (10) pre-anal length, (11) distance of the anus from the tip of the snout, (12) base length of the dorsal fin, and (13) base length of the anal fin.

Fin rays were counted in the dorsal, anal, and pectoral fins. Vertebrae were counted either on dried vertebral columns or from projected Röntgen-slides (24 × 36 mm). For gill-raker counts the first left gill branch was used consistently.

Measurements were expressed as percentages, those of the body as percentages of the total length, and those from the head region as percentages of the head length. All data of total fish length were grouped by one centimetre length groups and then averaged. These mean values were used for drawing percentage curves after having been smoothed in the usual way.

Results

Morphometric characters

All body proportions show a very strong variation and a considerable overlap in the different types of redfish. The percentage curves, however, are, on the whole, well separated, at least if the *mentella* and the *marinus* type alone are compared. The percentage curve of the intermediate fish lies between the two others, but oscillates much more than either of them. If all single percentage figures for any one character are plotted, no separate group of values is found, but always, without exception, the groups merge together. This means that no true differences exist, in a systematic sense, which would allow the fish to be treated as different species.

In contrast to this, in most cases *Sebastes viviparus* characters show well separated groups of observations so that there is no doubt that this fish must be considered as a separate species.

Numerical characters

A comparison of numerical characters of *Sebastes* types show few differences, but those of *Sebastes viviparus* stand out strikingly in Table 1.

Table I

Type	*marinus*	*mentella*	Intermediate	*Sebastes viviparus*
Number of fin-rays in D	XV/15·1	XV/14·8	XV/14·7	XV/13·7
Number of fin-rays in A	III/8·4	III/8·6	III/8·5	III/7·0
Number of fin-rays in P	19·1	18·9	18·9	17·5
Number of vertebrae	29·9	29·9	30·0	29·0
Number of gill rakers	35·2	34·5	34·6	37·7

Although the standard deviation has not yet been calculated, it is possible to suppose that the small differences shown in the values for the *Sebastes marinus* types lie within the limits of error.

As with the body proportions, the range of variation in the numerical characters is very great and overlap occurs if the types are compared. It may be added that the number of gill rakers in the giant fish is much lower than in the other types (34·2 and 33·6 in two samples), but since the number of specimens is rather small these figures may not represent the true average.

Discussion

From the results of these investigations there is no doubt that *Sebastes viviparus* must be considered as a true species. The different types of *Sebastes marinus,* however, show no differences either in their meristic or their numerical characters which would justify their being given the status of different species. At the moment it is not possible to decide the question of whether these types are subspecies, infra-species, or ecotypes, because corresponding investigations from all other parts of the North Atlantic have not yet been carried out. Nor could all length groups, beginning with the smallest bottom stages, be included in equal numbers. Below, three alternative possibilities are considered, to explain the existence of the three *Sebastes marinus* types.

1) Two different species existed, *Sebastes marinus* and *S. mentella,* having produced, by interbreeding, the intermediate fish, in which the genetic characters of one or of the other either predominate or are equally represented. In this way the occurrence of all transition

links could be easily explained. However, in this case typical *marinus* and *mentella* specimens might be expected among the smaller fish, as well as among the intermediate fish. But up to now only the latter have been found. This finding, however, does not preclude completely the possibility of interbreeding, for it could well be that the small *marinus* and *mentella* fish live in places where "Anton Dohrn" has not yet fished.

2) Originally there was one single species, *Sebastes marinus,* living in relatively shallow water. From this species fish have gradually penetrated into deeper waters, and have changed their external appearance in adapting themselves to the new conditions of life. If this development is not yet completed, then the species is in "stato nascendi" and the occurrence of intermediate type fish could be readily explained. The question of where the smaller deep sea redfish live still remains, however, for it seems rather improbable that only specimens above about 30 cm in length would penetrate to live in deeper waters.

3) All the types originated from the intermediate fish, from which either the *marinus* or the *mentella* type fish developed according to the preferred depth, whilst some of the fish, living under intermediate conditions, remained at the status of intermediate type fish. This theory too, however, is not satisfactory in every respect, since it infers that the larvae of all types of fish would show no differences. In the field investigations up to now only differences between larvae of *Sebastes viviparus* and *Sebastes marinus* have been described, but Templeman (1959) who used pre-extrusion larvae for comparison, found typical differences between the North American *marinus* and *mentella* type larvae, which might possibly occur in other parts of the North Atlantic, too. But this can be decided only by further investigations.

A. 4

Preliminary Remarks about Redfish Otoliths

By
ADOLF KOTTHAUS
Biologische Anstalt Helgoland, Bremerhaven

When studying redfish otoliths for age determinations some interesting observations about the external feature and the growth of otoliths were made.

In Plates 1 and 2 redfish otoliths from different areas of the North Atlantic between Barents Sea and Labrador are compared. It is not difficult to observe that the otoliths of the samples are of very different appearance. Only the most striking features are dealt with here. The samples which should be compared first are samples Nos. 2, 5, and 16 from the Norwegian coast, the Iceland-Faroe Ridge, and from Labrador, for which the otoliths were taken from fish of 44 to 46 cm total length. No. 2 shows the common features of *marinus*-type otoliths. They are rather thin and slender. Their dorsal margin is slightly serrated in comparison with the ventral, which is rather smooth. The anterior part of the otoliths is deeply furcated. *Marinus*-type otoliths from other regions in general show the same features, with only small deviations, as may be seen from samples Nos. 6, 7, and 8 (south-east Iceland, south-west Iceland, and West Greenland). In contrast to these the *mentella*-type otoliths (No. 5) are much thicker (not visible in the photograph) and noticeably longer. The teeth of the dorsal margin are much broader, more rounded, and more marked. In many cases the furca is almost absent, or at least it is not as pronounced as in the *marinus*-type otoliths. Thus these otoliths give the impression of being degenerate, similar to the gill rakers, as pointed out in the "Contributions to the race problem in redfish". It may be added that the *mentella*-type otoliths have a very distinct radial sulcus, which is seen best by transmitted light.

These two types of otoliths differ very much from those of the North American (Labrador) redfish (No. 16). The latter are very broad and relatively thick. The dorsal margin is almost entirely smooth, but the ventral border in general is sharply serrated by a great number of small and acute teeth (which do not appear clearly in the photograph). The angle between the two branches of the furca is somewhat rounded and not always very clear (compare sample Nos. 9 and 10 of smaller rosefish which are of the same appearance). These otoliths resemble most closely those of *Sebastes viviparus*.

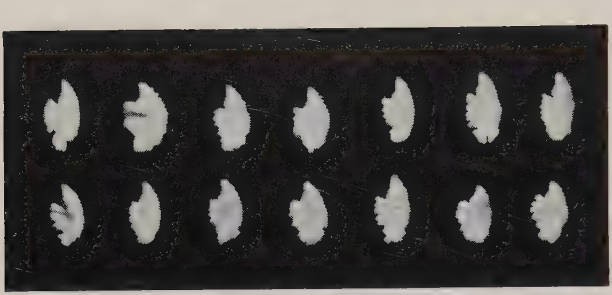
The intermediate type redfish have otoliths resembling partly *marinus*, partly *mentella* otoliths, whilst some of them have characters of both types. In many cases they also give the impression of being more or less degenerate (Nos. 1 and 3).

The otoliths of giant redfish, as shown by samples Nos. 11 to 15, mostly resemble the *marinus* type, especially in respect of the formation of the furca, which in general is well developed. Only the otoliths of giants from the Norwegian coast (No. 11) differ somewhat and resemble more the *mentella* type, especially in the formation of the dorsal border; also, their size is much more variable than in otoliths of giants from other regions.

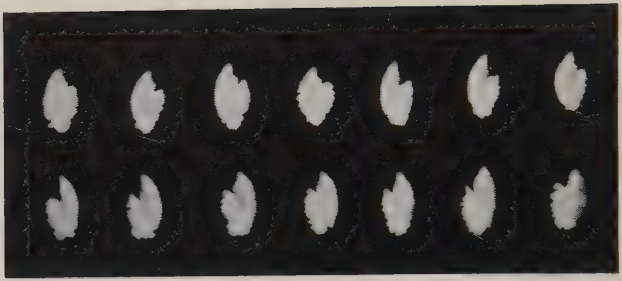
Because of these differences it is possible in most cases to decide, by comparison, from which type of fish the otoliths are taken or from what region of the North Atlantic the fish are derived. Since the range of variation of the single characters overlaps in the different types, it is necessary to have at hand a large number of otoliths for comparison in order to see the mode variation.

Not only are the otoliths of the different types of redfish distinguishable from each other, but on the whole each type exhibits differences from area to area–see, for example, the differences between the *mentella*-type otoliths from the Iceland-Faroe Ridge (No. 5) and those from the Bear Island region (No. 4) which infer two separate populations.

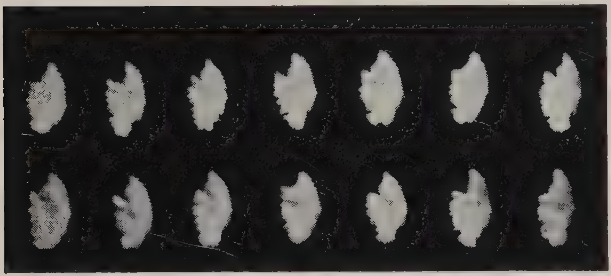
The length of the *mentella* otolith is obviously



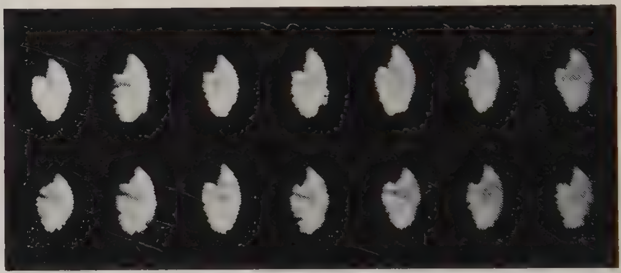
No. 1. Barents Sea; type intermediate; total length 44–46 cm.



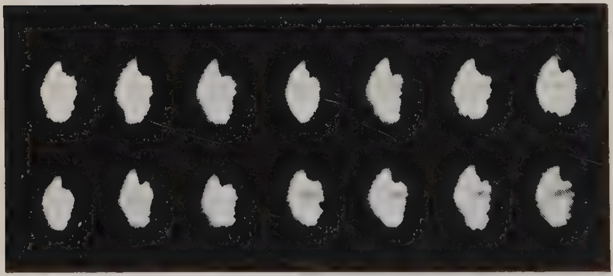
No. 2. Norwegian coast; type *marinus*; total length 44–45 cm.



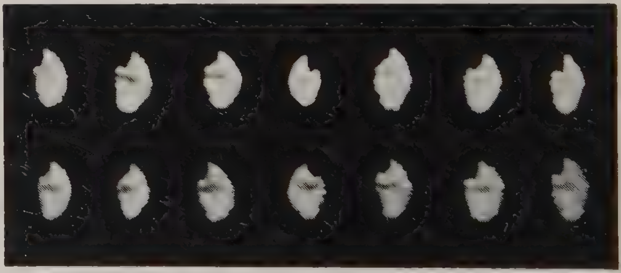
No. 5. Iceland–Faroe Ridge; type *mentella;* total length 44–46 cm.



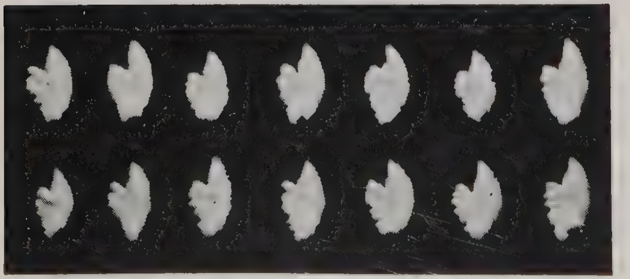
No. 6. Iceland SE coast; type *marinus*; total length 44–46 cm.



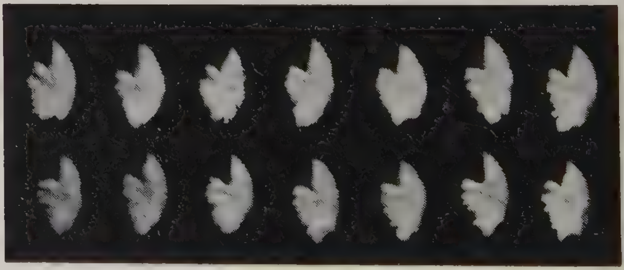
No. 9. Newfoundland; type rosefish; total length 35–36 cm.



No. 10. Labrador; type rosefish; total length 35–36 cm.

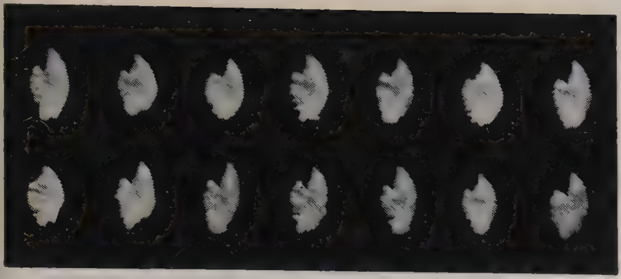


No. 13. Iceland NW coast; type giants; total length 65–67 cm.

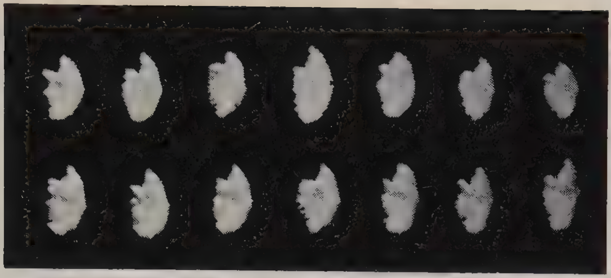


No. 14. Greenland E coast; type giants; total length 65–67 cm.

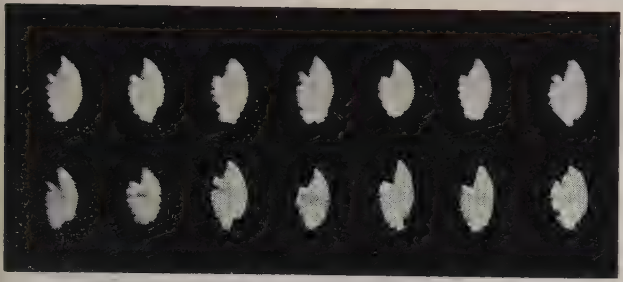
Plates 1–2. Redfish otoliths from different type



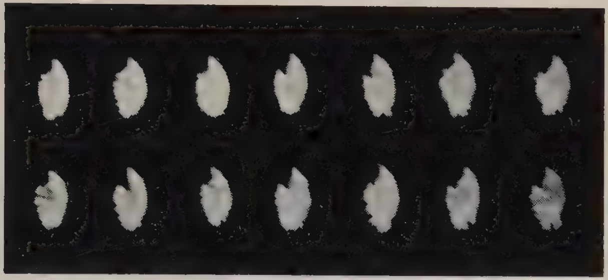
No. 3. Norwegian coast; type intermediate;
total length 44–46 cm.



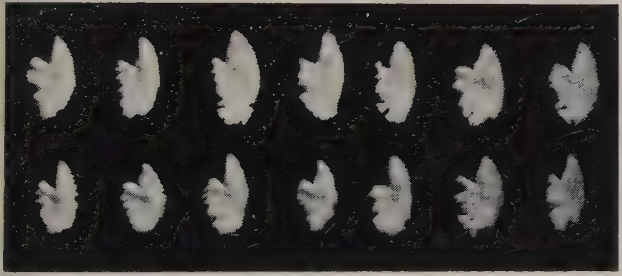
No. 4. Bear Island; type *mentella*;
total length 43–46 cm.



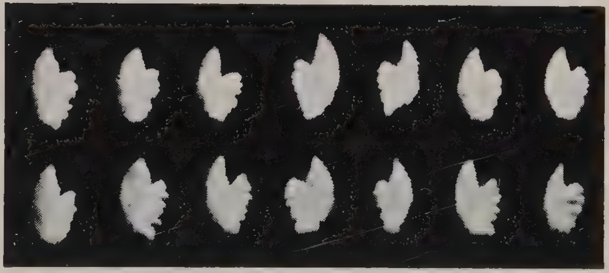
No. 7. Iceland SW coast; type *marinus;*
total length 44–46 cm.



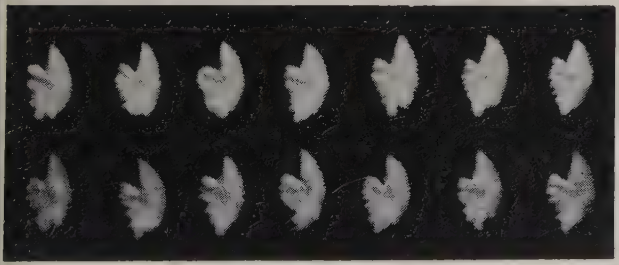
No. 8. Greenland W coast; type *marinus*;
total length 44–46 cm.



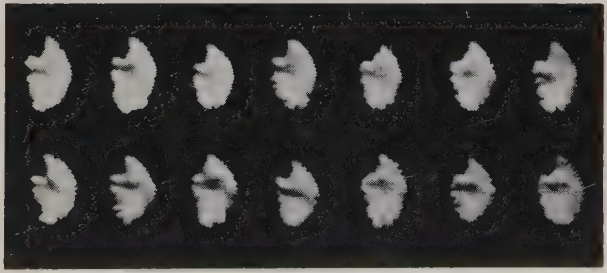
No. 11. Norwegian coast; type giants;
total length 65–66 cm.



No. 12. Iceland SW coast; type giants;
total length 64–67 cm.



No. 15. Greenland W coast; type giants:
total length 65–67 cm



No. 16. Labrador; type giants;
total length 44–46 cm.

ent areas of the North Atlantic.

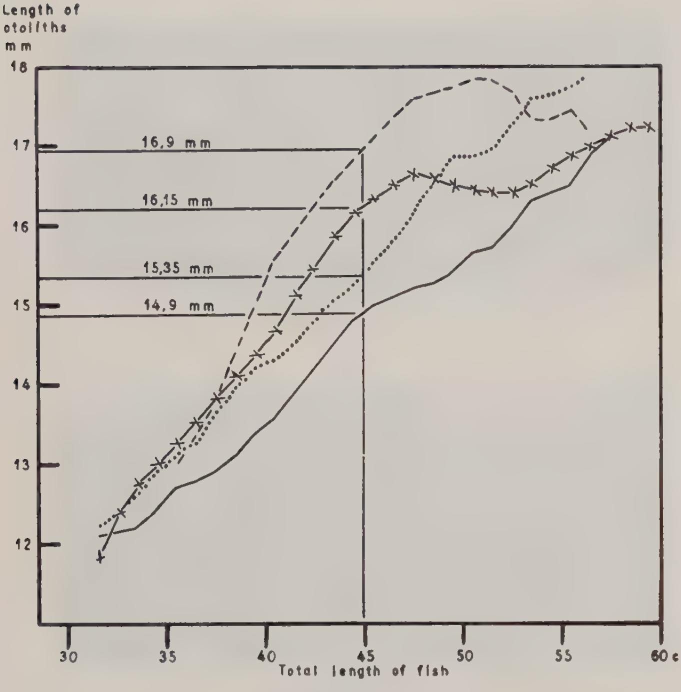


Figure 1. Growth curves of redfish otoliths from four different areas.
——— = W Greenland, *marinus* type (539 measurements).
x–x–x– = E Greenland, interm. type (740 measurements).
– – – – = Iceland-Faroe Ridge, *mentella* type (1,452 meas.).
········ = Norw. coast, *marinus* type (1,387 measurements).

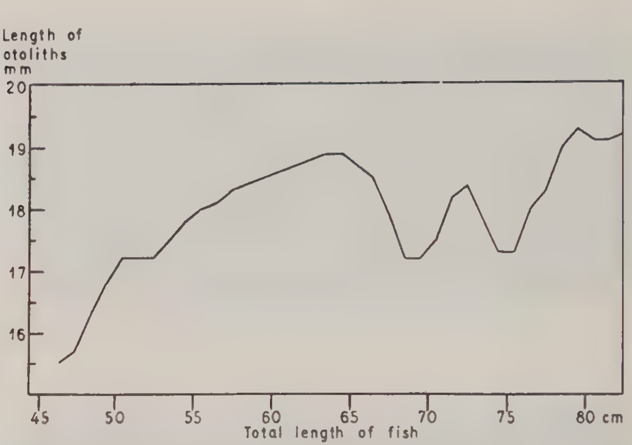


Figure 2. Growth of redfish otoliths from the Lofoten area 1959.

greater than that of the *marinus* otolith, but there are other differences between the types which also persist from area to area. In general the differences are not striking and are not seen by a superficial glance at the material; they appear most clearly in the growth curves of the otoliths. In order to examine this feature the maximum length of about 30,000 redfish otoliths was obtained by a special apparatus reading to $^1/_{100}$ mm. The observed values were rounded off to the nearest $^1/_{10}$ mm. For each centimetre of total fish length the average length of otoliths was calculated, and the growth curves of Figures 1 to 5 were drawn from these averages.

Figure 1 depicts the growth curves of redfish otoliths of four different areas, which show at once that the otoliths of West Greenland fish are the slowest growing. Those from the Norwegian coast are somewhat faster growing. In both cases *marinus*-type otoliths were chosen exclusively. The growth curve of redfish otoliths from the Iceland-Faroe Ridge area is very clearly distinguishable from those of the other two regions; here the growth-rate is much higher. This curve derives from samples in which the types of fish were not separated. The smaller fish up to about 47 cm total length are exclusively of the *mentella* type, whilst the larger fish were some *marinus*-type redfish and some giants. This characteristic growth curve for the Rosengarten otoliths is dependent upon the mixed population – the curve flattens out because the *marinus*-type otoliths and those of the giants are very much slower growing than the *mentella*-type otoliths. The giant fish, in particular, have very slow-growing otoliths. (This is demonstrated from a large material from the Norwegian coast (Fig. 2) in which the smaller fish are mostly of the *marinus* type. The bigger ones from about 60 to 65 cm are giants. The changes in the curve here

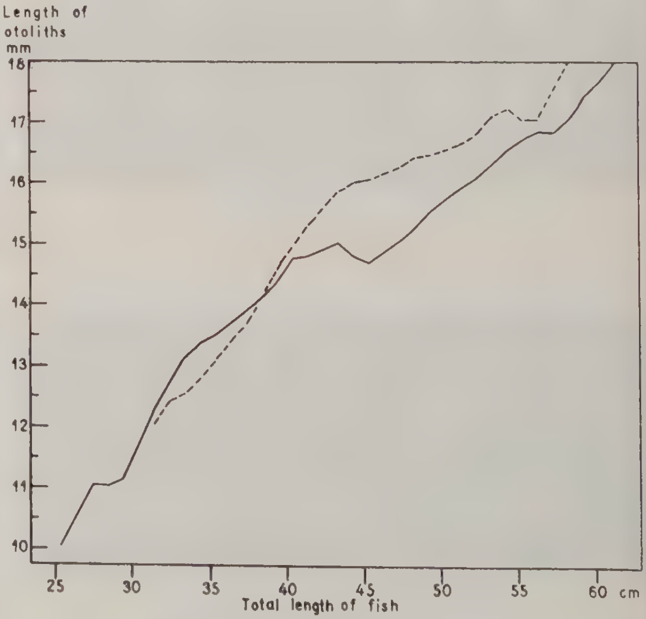


Figure 3. Comparison of otoliths of the American rosefish (whole line, Newfoundland, 202 measurements) with those of the *marinus* type (dashed line, SW Iceland, 1,411 measurements).

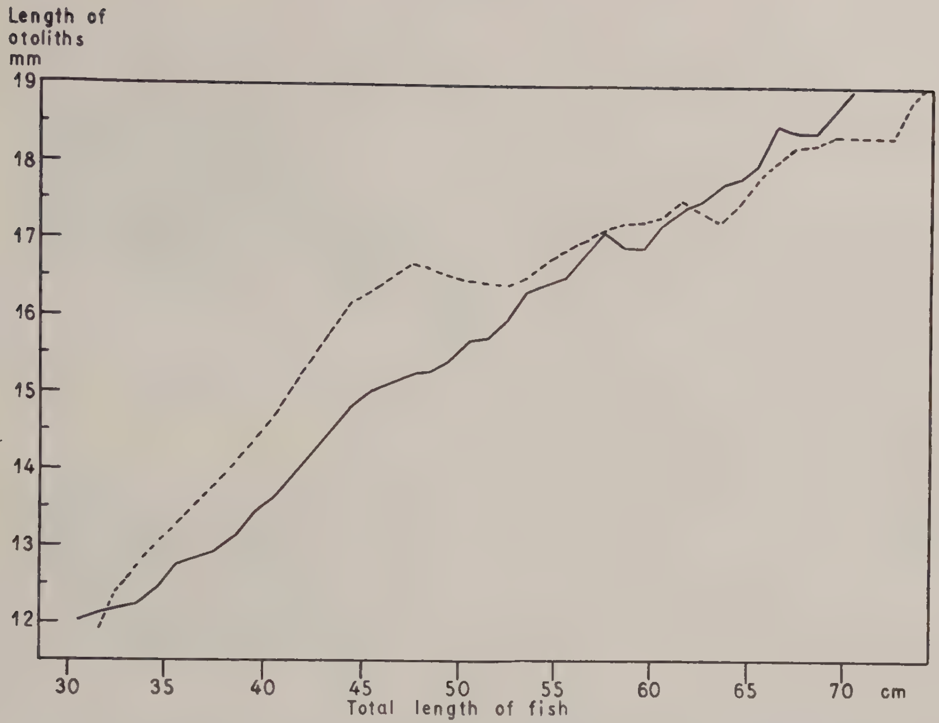


Figure 4. Difference between otolith growth of West and East Greenland redfish.
——— = West Greenland (539 measurements)
– – – – =East Greenland (1,391 measurements).

are also caused by the fact that both kinds of fish occur at the same length.) The growth curve of intermediate type otoliths is drawn for East Greenland (see Fig. 1). Up to about 47 cm total length it is intermediate between those of the *marinus* and the *mentella* type. Above this length it approaches the *marinus*-type curve. This is the typical form of growth curve of intermediate fish otoliths. It must be mentioned that the length at which the two curves approximate differs somewhat from area to area. This is shown in Figure 5, for material from south-west Iceland and from the Iceland-Faroe Ridge.

It should be noted that the differences in the length of otoliths and in fact in growth-rate generally, become evident from about 30 cm total fish length onwards. Otoliths of smaller fish of different types are hardly distinguishable in length.

Comparing otoliths of the American rosefish with those of the *marinus* type (Fig. 3) no essential differences are to be seen up to about 37 cm, but for otoliths of larger fish the growth-rate is much greater in the rosefish.

Figure 4 once more shows the differences between the otolith growth from West and East Greenland redfish, including giants up to about 75 cm. The West Greenland material consisted almost exclusively of *marinus*-type fish up to about 65 cm, whilst in the East Greenland material there were intermediate types in the smaller fish up to about 47 cm, *marinus* fish up to about 63 cm, and the largest fish from about 63 cm onwards were mostly giants. In the West Greenland material the growth-rate of the *marinus* and giant fish otoliths does not differ much, and the curve suffers no appreciable deflection. In the East Greenland material, however, the giant fish otoliths grow somewhat more slowly than those of the *marinus* type, and these latter again more slowly than intermediate type otoliths. It was therefore the composition of this sample which was responsible for the two distinct peaks in the curve.

Sometimes big fish of the *marinus* type and giants of the same length cannot be readily distinguished from each other by their external appearance. In such cases the otoliths are a good guide. Figure 6 demonstrates this by a schematic drawing. Looking at an otolith of the *marinus* (or *mentella*) type fish by transmitted light, the centre of the otoliths up to the first spawning zone has generally four, sometimes five broad annual rings, implying that these fish mature for the first time at an age of four to five years. In contrast to this, the

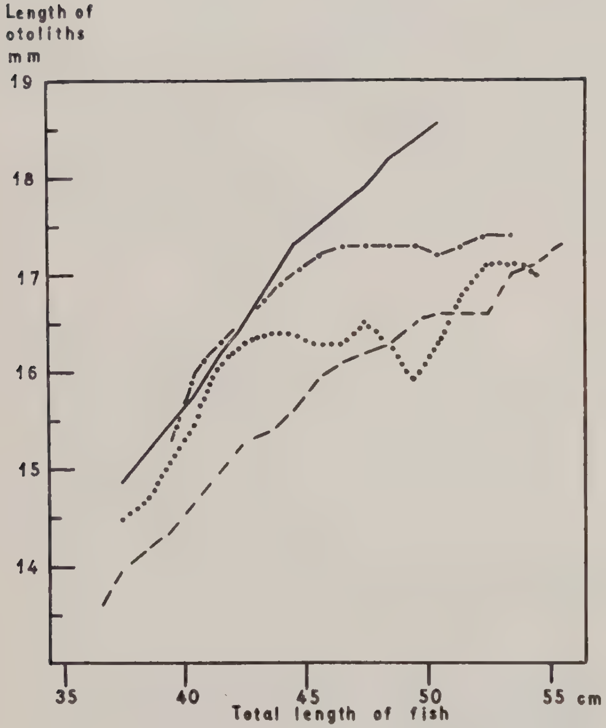


Figure 5. Length of otoliths from different areas.

———— = Iceland-Faroe Ridge – type: *mentella*
–·–·– = Iceland-Faroe Ridge – type: intermediate
– – – – = Iceland, south-west coast – type: *marinus*
……… = Iceland, south-west coast – type: intermediate

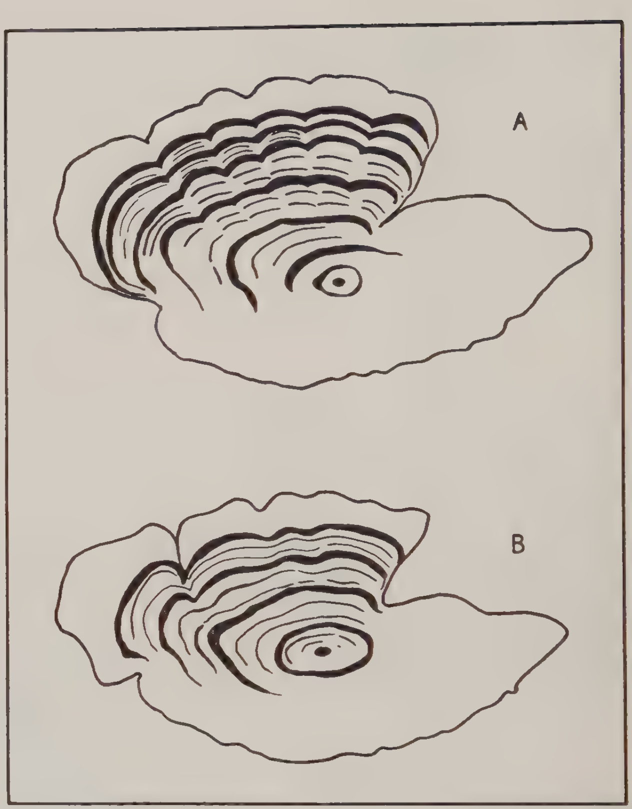


Figure 6. Schematic view of two otoliths in transmitted light.

A = Giant redfish showing 7 broad annual rings before the first spawning.
B = Type *marinus*, showing only 4 broad annual rings before the first spawning.

The additional, very narrow rings are not shown.

giant fish have in general six to seven annual growth zones before the beginning of the very narrow rings laid down after their first spawning. This observation strengthens the view that giants are not to be looked upon as merely large *marinus* fish.

The question might be asked, "Why this great use of otoliths?" Now, these observations are of great value in distinguishing different redfish types in former otolith samples, since in the first years of sampling, otolith types were not separated. It is now possible, for instance, to decide from the growth curve of otoliths whether the sample is of *mentella, marinus,* or intermediate fish, or if it is a mixture of otoliths of different types. The external appearance of the otoliths is also a valuable help for separating otoliths. Finally, it is possible to decide whether a large redfish is of the *marinus* type or a giant fish, by examining the internal structure of the otoliths.

A.5

Problems in the Identification of Fishes, with a Comparison between Shallow-Water and Deep-Water Species of *Sebastodes* (Scorpaenidae)

By
J. B. PHILLIPS
Marine Resources Operations, California Department of Fish and Game,
Sacramento, Calif., U.S.A.

The task of a fish systematist is not easy: often he is faced with inadequate type descriptions, species lacking distinctive external characters, forms that undergo certain morphological changes with age, and other related problems.

A great deal has been written on the subject of what does or does not constitute a species. In some cases, young of previously described adult forms have been described as new to science, usually in good faith because forms of intermediate size were not available at the time. Also, on occasion a specimen of a previously described species has, on the basis of certain variations, been separated and described as new. Because of poor original descriptions for the species in question such action may be excusable.

Even though a species has been adequately identified, the fisheries biologist who is concerned with population studies may not be satisfied. In the management of fish populations it is necessary to know what separable units are present and how they can be identified.

Although species separation in fishes is usually based on morphological features of form and structure, in racial studies physiological characteristics such as growth-rate, time of spawning, and migration patterns might be used. According to Kesteven (1950): "There does not seem to be any reason why almost any feature whatsoever could not constitute a racial character, whether a minor morphological feature, a physiological one, an ecological habitat, or a preference for a certain food. Any of these could be demonstrable and constant."

Morphological Characters

Morphological characters may be grouped either as those that can be examined externally, or those involving dissection and internal examination. Morphological characters reducible to digits can be grouped either as meristic counts or proportional measurements. In counting the number of spines or rays in the median fins, it may be found that some of the anterior or posterior elements are minute or buried beneath the skin. This was true with the Pacific coast sablefish, *Anoplopoma fimbria,* a demersal species found to depth of at least 400 fathoms (Phillips, Clothier and Fry, 1954). This situation does not exist in species belonging to the genus *Sebastodes.*

Sometimes a character simplifying field identification may go unnoticed for years. Only recently a fisheries biologist discovered that invariably Pacific coast silver salmon (*Oncorhynchus kisutch*) differ from king salmon (*O. tshawytscha*) in having the crown of the gums through which the teeth protrude white, in contrast to all dark gums in the king salmon. Previously, separation of these forms when similar in size, was difficult under field conditions. A positive internal character — fewer than 85 pyloric caecae in the silver and more than 100 in the king — is of little avail when salmon are landed in a cleaned condition.

Some systematists working on species lacking in differentiating characters have been tackling the problem facing them by an examination of internal anatomy, larval characters, and type of blood.

Internal anatomy

Godsil and Byers (1944), following the style of Kishinouye (1923), found proportional measurements and meristic counts of little value for distinguishing five Pacific tunas, and external colour was specific for only one. However the appearance of the viscera was a valuable identifying character for all five species. When the walls of the body cavity were cut away exposing a ventral view from heart to anus, it was found that the position and visible amount of the caecal mass, liver, stomach, intestine, and spleen were characteristic for each species. Furthermore, such characteristics as a striated or non-striated liver, a straight or folded intestine, a conspicuous or inconspicuous gall bladder, and presence or absence of an air bladder, were invariable to each species. Additional items of value in specific determination of the five tunas were: the vertebra under which the kidney terminated; the vertebra under which the ureter divided, and the type of divergence; the number of branches to the coeliac-mesenteric artery; the presence or absence of a conical plexus; the position of the anterior arterial, the cutaneous system and, if present, the post-cardinal vein.

To facilitate their study of the blood-vascular system, Godsil and Byers made injections of red and blue latex. Various osteological comparisons also were made, but only the bones of the cranium and the spinal column provided the most useful characters.

As a result of establishing the validity of five species of tuna by comparing internal features, Godsil (1945) later produced a satisfactory field key for the identification of these fish.

This field key is based primarily on external characters, but has the added protection of a specific internal character where an external feature may be questionable.

Further evidence that a thorough examination of internal anatomy might be productive in speciation and racial studies is indicated in a recent article by Harder (1958). He found that the anatomy of the intestine is useful in identifying systematic groups, such as the Engraulididae, Clupeidae and Dussumieriidae. He suggested that the length of the intestinal tract might be a useful racial character. Since intestinal length increases with fish length, comparisons would have to be made by calculating regressions of intestinal length on standard length. Harder pointed out that among the Engraulididae, *Cetengraulis mysticetus* and *Anchovia macrolepidota* are somewhat alike externally, except for a thin membrane connecting the gill covers in *Cetengraulis,* but differ enormously in the gross anatomy of their intestines. In *Cetengraulis* the intestinal length, from anterior end of mouth to anus, is 6 to 10 times the standard length, while in *Anchovia* the intestinal length is but 1·24 times the standard length. Likewise, the gross appearance of the intestine differs.

Vertebral characters

Following the work of Ford (1937), who described and illustrated differences in the vertebral columns of several fishes, Clothier (1950) produced a key to the identification of 163 species of teleostean fishes taken off the coast of southern California. The main portion of the key was based on the total number of vertebrae, and the vertebra upon which occurred the first haemal spine and the first haemal arch. Secondarily, and in the more complex parts, additional osteological characters were taken into account, such as the size and shape of the bones of the skull, size and shape of the haemal and neural spines, and other bony peculiarities.

Such a key is of little help, however, in separating species of *Sebastodes* because the total number of vertebrae in the spinal column is invariable. Clothier reported upon 39 specimens representing 10 species from southern California waters, and including the urostyle, the total vertebrae in all but one was 26. In one instance a count of 27 was found. In all cases, the first haemal spine appeared on the twelfth vertebra.

Vertebral counts in the other species of *Sebastodes* probably are similarly invariable. Jordan and Evermann (1898), used a vertebral count of 27 in separating *Sebastodes* and *Sebastopsis* from other genera of Scorpaenidae. This is one more than Clothier found in the species he examined. But, Clothier counted the urostyle as a single element, even though the upper lobe is jointed and undoubtedly was counted as two by Jordan and Evermann.

Larval identification

Morris (1956) in presenting descriptive information on the early larvae of *Sebastodes paucispinis, S. goodei, S. jordani,* and *S. saxicola,* noted differences in melanophore patterns that were characteristic for each. Although specific identification of all 49 species of larval *Sebastodes* occurring in California waters might prove difficult, the problem on the Atlantic coast should be simplified by the presence of but a few forms of *Sebastes.* Also, it might be possible to rear the larvae of such ovoviviparous species to an advanced size, thus affording a greater possibility of observing recognizable differences.

That *Sebastodes* larvae lead a pelagic existence is noted in a report by the Marine Research Committee (1952). In plankton hauls they were widely distributed along the California and Baja California coasts during every month of the year. Their persistent occurrence up to 300 miles offshore suggests that some species lead a pelagic existence.

Blood tests

Serological techniques, wherein the serum of blood is used as a means of distinguishing racial groups, are currently under investigation. At present, the U.S. Bureau of Commercial Fisheries, in its studies of North Pacific salmon, and the Inter-American Tropical Tuna Commission, in its study of South Pacific tunas, are both actively exploring this approach to possible specific and sub-specific separation.

Scorpaenid Fishes

In a systematic review of the rockfishes (Scorpaenidae) in California waters, Phillips (1957) identified 49 species of *Sebastodes*, two of *Sebastolobus* and one of *Scorpaena*. An artificial key based on characters that did not involve dissection was provided. Morphometric measurements were converted to proportions rather than to percentages of standard length. Specific descriptions included but one internal character – the colour of the peritoneum. An examination of other internal features was not undertaken.

Shallow-water versus deep-water form

To determine the differences that might be associated with shallow-water as contrasted to deep-water *Sebastodes*, six species associated with each depth zone were selected for analysis of morphometric measurements. The shallow-water forms selected were: *S. mystinus, S. rastrelliger, S. carnatus, S. chrysomelas, S. caurinus,* and *S. serriceps.* The maximum depths reported for these are 25 to 50 fathoms, and the maximum reported total lengths range from 15 to 20 inches (38 to 51 cm). The deep-water species selected were: *S. saxicola, S. crameri, S. aleutianus, S. aurora, S. diploproa,* and *S. rubrivinctus.* The maximum depths reported for these are 200 to 300 fathoms, and the maximum reported total lengths range from 13 to 33 inches (33 to 84 cm).

After completing a comparison of these 12, another six species occurring in waters of intermediate depth were compared. The species used in this analysis were: *S. paucispinis, S. goodei, S. entomelas, S. pinniger, S. miniatus* and *S. levis.* The maximum total lengths range from 21 to 36 inches (53 to 91 cm). Between 45 and 75 specimens were examined in each group of six species.

The various morphometric measurements for each fish were converted to percentages of standard length, and these percentages were plotted against the standard length in order to observe the trends and ranges of the ratios. Comparisons were made in the size range of 4 to 14 inches (10 to 35 cm), standard length, because none of the shallow-water forms in this analysis exceeded 14 inches (35 cm).

For a comparison of the meristic and other general features, all 49 species of *Sebastodes* reported from California waters were grouped by maximum depth of occurrence. The three groupings used and the number of species fitting each were: shallow water (0–99 fathoms; 20 species), intermediate water (100–199 fathoms; 17 species), and deep water (200–300 fathoms; 12 species). Between 240 and 290 specimens were examined in each of the three categories.

The following summary illustrates the magnitude of the morphometric, meristic, and other features resulting from these analyses:–

Shallow-water species

Greater maxillary length
Greater body depth
Greater length of fin rays and fin spines
Shorter gill rakers
Greater proportion of species with a white, rather than a dark peritoneum.

Intermediate water species

Greater width of interorbit
Greater number of gill rakers
Greater number of lateral line pores
Greater number of longitudinal rows of scales
Greater average maximum length of fish
An equal proportion of species with a white, as with a dark peritoneum.

Deep-water species

Greater width of orbit
Greater length of head
Stronger spines on head
Stronger symphyseal knob at tip of lower jaw
All species with a dark or black peritoneum.

The average number of dorsal, anal and pectoral fin rays, and the snout length were not significantly different.

Allometric growth of various body parts for *Sebastodes*, regardless of depth distribution, was sufficiently similar to be included in general summaries, as follow:–

Rate of increase significantly slower than increase in standard length

Width of orbit
Length of second anal fin spine
Length of ventral fin spine

Rate of increase generally slower than increase in standard length

Longest dorsal fin spine
Longest dorsal fin ray
Longest raker on first gill arch

Rate of increase generally faster than increase in standard length

Length of head
Length of snout
Length of maxillary
Width of interorbit
Greatest body depth

Rate of increase variable but generally constant with standard length

Longest pectoral fin ray
Longest ventral fin ray
Longest anal fin ray

It should be pointed out that the foregoing analyses were based on material that was previously processed in a systematic study of the Scorpaenidae in California waters. Four to five inch fish (10 to 13 cm) were not available for all species. Likewise, in some cases material in the larger sizes was not available because of the relatively short maximum lengths attained by some rockfish. Therefore, these analyses should be considered as provisional until a more critical study can be made with a series of a comparable size.

The inclusion of juvenile sizes is important in a morphometric study, if trends based on an increasing standard length are to be representative. Recently, a small *Sebastodes,* one inch in standard length, was sent to me for identification. Fortunately, the gill raker count was sufficiently low to narrow its identity to one of three species. Two of these were disqualified on the basis of the pectoral fin ray counts and the absence of certain cranial spines. The remaining possibility, *S. rastrelliger*, qualified in every respect except for long and slender gill rakers. Phillips (1957) noted a key character for *S. rastrelliger* as: "Rakers on first gill arch short and flat, about as high as wide but not more than two times high as wide;" However, since publication two small specimens, one 4·5 inches (11·5 cm) in standard length, have been obtained. The gill rakers in the 4·5 inch specimen were somewhat longer than indicated for the key character, being 2·6 per cent of standard length, compared with 1·4 to 1·8 per cent for a series of specimens 6·4 to 13·7 inches (16 to 35 cm) in standard length. The longest gill raker in the one-inch specimen was 5·0 per cent of standard length. Thus it would appear that the gill rakers in juvenile *S. rastrelliger* are proportionately as long as the rakers in a number of other species, but become progressively shorter with age. *S. rastrelliger* lives among kelp in rocky areas, close to shore.

Conclusions

In a tentative analysis of external characteristics of Pacific coast species of *Sebastodes* (Scorpaenidae), comparisons were made between shallow-water and deep-water forms. Consistent differences were not apparent in all cases. The average number of dorsal, anal, and pectoral fin rays was found to be essentially identical for all species.

Shallow-water forms generally had longer maxillaries, deeper bodies, longer fin spines and rays, and shorter gill rakers. Wider orbits, longer heads, stronger head spines, and stronger symphyseal knobs were associated with species living in deep water (200–300 fathoms). However, those living in waters of intermediate depth (100–199 fathoms) are characterized by having the greatest number of gill rakers, lateral line pores, and longitudinal rows of scales on the body. Also *Sebastodes* found at intermediate depths attain the greatest average maximum length.

The rate of increase in width of orbit, length of second anal spine, and length of ventral fin spine was significantly slower than it was for standard length. In general it was also slower for the dorsal fin elements and the gill rakers. It was generally faster for snout, head, and maxillary lengths, and for interorbital width and body depth.

When external characters are not entirely satisfactory for typing species of fishes, it is suggested that an examination of the internal anatomy be undertaken. In recent years workers have shown that important differences are sometimes evident when comparing internal organs, while differences in external features may be difficult to evaluate.

Newly hatched larvae of ovoviviparous fishes may reveal consistent specific differences in the melanophore pattern, or other features.

Currently, serological techniques or blood tests appear to hold promise for identifying North Pacific salmon stocks and South Pacific tuna stocks. If successful, such methods could be applied to other stocks, such as the scorpaenoid fishes.

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A.6

Vertebral Numbers of Redfish, *Sebastes marinus* (L.), in the North-West Atlantic, 1947-1954

By

WILFRED TEMPLEMAN and T. K. PITT

Fisheries Research Board of Canada, Biological Station, St. John's, Nfld.

Part 1

Redfish Vertebral Numbers and Averages in the North-West Atlantic

Introduction

During the period 1947–1954 vertebral counts of redfish, *Sebastes,* were made at the St. John's station. The fish were first filleted and the fresh or salted skeletons were boiled for a short period; then the vertebral columns were placed on a wire screen set at an angle and the flesh was thoroughly cleaned off by water from a pressure hose. The vertebral columns were dried immediately in a small salt fish dryer. All whole vertebrae between but not including the basioccipital bone and the urostylar half-vertebra were counted. For purposes of this paper, all skeletons with fused vertebrae were discarded; these were not numerous. All vertebral columns were examined by several people. Two vertebral counts in agreement were made by a technician, and a third check count was done, usually by a biologist; also, the senior author has consistently checked 5 % to 10 % of the counts and usually all exceptional counts for each sample and such greater numbers as were necessary whenever inaccuracies were noted.

During the period covered by this paper *Sebastes marinus marinus* (L.) and *Sebastes marinus mentella* Travin were not separated. Over most of the area the *mentella* type is greatly predominant (Templeman, 1959). *Marinus*-type redfish live shallower (at least during late spring, summer, and autumn), grow larger and become sexually mature at larger sizes than *mentella*; also the sizes, depths, and sexual maturities of these redfish, together with knowledge of the distribution of the *marinus* and *mentella* types in the area, indicate that there is little error in assuming almost all these redfish to be *mentella*. There are a few cases, however, where it is indicated that a larger or smaller proportion of the sample may be *marinus* type. These will be noted.

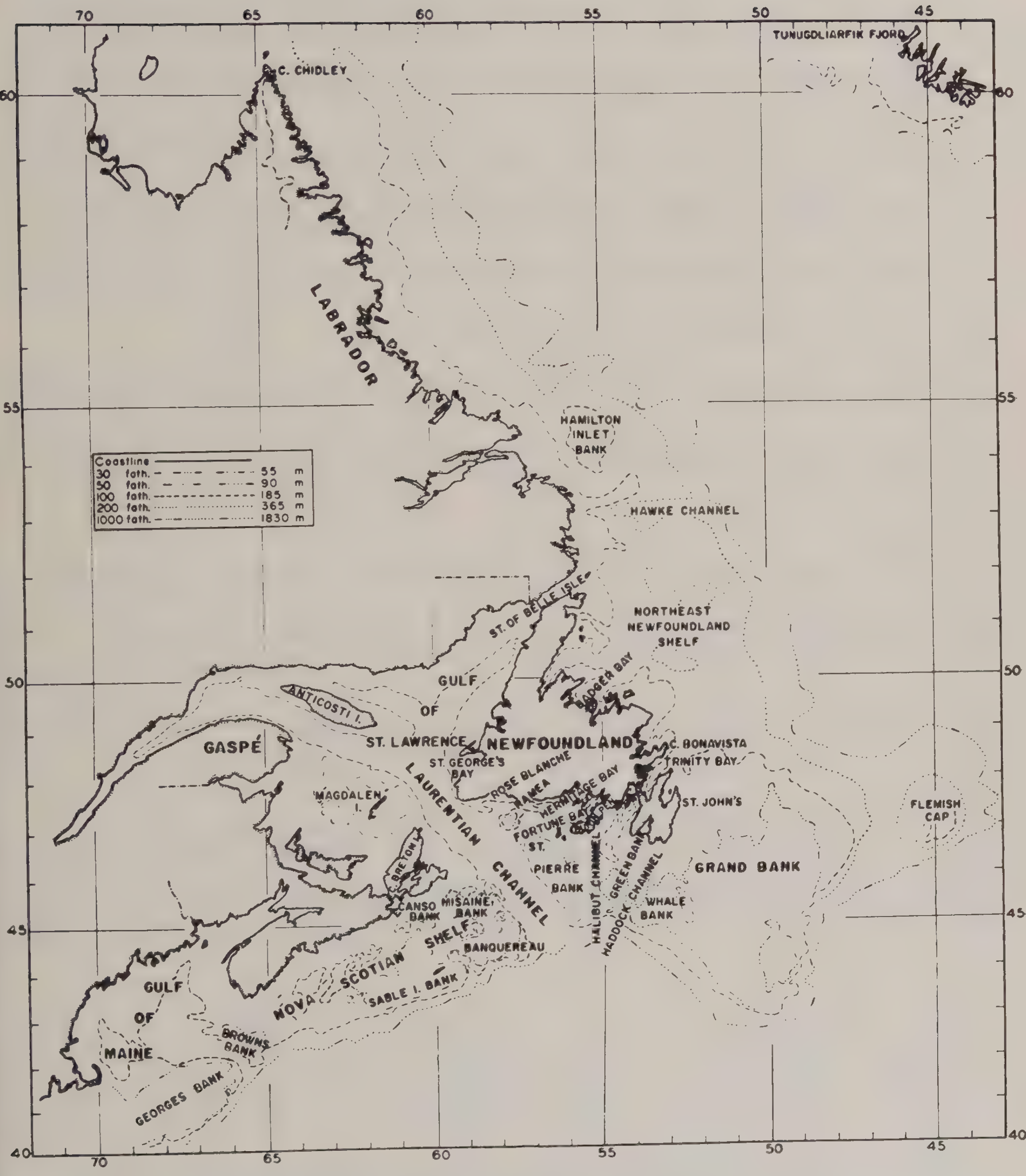
A list of all vertebral samples and data relating to them is given in Table 1, and place names are shown in Figure 1. Only random samples were used for Figures 2–14 and Table 1.

The vertebral numbers of individual redfish ranged between 28 and 31; each sample was usually restricted to only 2 or 3 numbers (Table 1, Figures 3–7). This produces a sharply peaked vertebral number curve, but it is assumed that standard statistical methods will apply, although, for reasons which will develop later in this paper, statistical comparisons of vertebral averages from random samples will not be argued too rigidly. For the convenience of the reader in making his own comparisons, the standard error is given for the average vertebral numbers in Table 1 and the numbers of redfish in the samples are shown in Figure 2. Almost all samples were of 110 to 120 fish and very few were below 50.

In these samples differences between vertebral averages (Figure 3) of 0·2 or over will usually be significant. In view of data to be presented later it is not worth while to push the argument regarding statistical differences too closely, but major differences may often be noted with confidence.

A redfish sample obtained from Tunugdliarfik Fjord, West Greenland, in 1956 has been included for comparison. These redfish were of the *mentella* type and had a vertebral average of 30·04, similar to the usual Labrador average.

It is apparent that the Labrador samples from Lat. 60° to 54° N, with vertebral averages of approximately 30·0, are most significantly distinct from those of the Gulf of Maine with averages of 29·0, from the Nova Scotian Shelf samples, with averages of 29·1—29·2, and from Flemish Cap and the eastern, southern, and southwestern Grand Bank samples, in which vertebral


70
65
60
55
50
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60
55
50
45
40
TUNUGDLIARFIK FJORD
C. CHIDLEY
LABRADOR
HAMILTON INLET BANK
HAWKE CHANNEL
Coastline
30 fath. 55 m
50 fath. 90 m
100 fath. 185 m
200 fath. 365 m
1000 fath. 1830 m
ST. OF BELLE ISLE
NORTHEAST NEWFOUNDLAND SHELF
BADGER BAY
GULF OF ST. LAWRENCE
ANTICOSTI I.
GASPÉ
NEWFOUNDLAND
C. BONAVISTA
TRINITY BAY
ST. GEORGE'S BAY
ROSE BLANCHE
RAMEA
HERMITAGE BAY
FORTUNE BAY
ST. JOHN'S
FLEMISH CAP
MAGDALEN I.
LAURENTIAN CHANNEL
C. BRETON
ST. PIERRE BANK
GRAND BANK
HALIBUT CHANNEL
GREEN BANK
HADDOCK CHANNEL
WHALE BANK
CANSO BANK
MISAINE BANK
BANQUEREAU
NOVA SCOTIAN SHELF
SABLE I. BANK
GULF OF MAINE
BROWNS BANK
GEORGES BANK

Figure 1. Reference map including most localities mentioned in the text.

Table 1
Vertebral numbers of redfish from the North-west Atlantic, 1947-1954

Sample number	Year	Month	Locality	Position Lat. N	Position Long. W	Depth fath.	Depth m	Bottom temp. °C	Vertebral frequency (%) 28	29	30	31	Total fish	Vert. av.	Stand. dev.	Stand. error	Av. fish length* cm
0	1956	Oct. 20	Tunugdliarkfik Fjord	60°56′	45°47′	161	294	–	–	1·89	92·45	5·66	53	30·038	0·275	0·038	18·30
1	1950	Aug. 23	Off Cape Chidley	60°25′	61°57′	160–209	293–382	2·91	–	3·26	94·57	2·17	92	29·989	0·234	0·024	27·50
2	1950	Aug. 31	Off Labrador	55°40′	57°08′	175–185	320–338	1·83	–	8·62	84·48	6·90	116	29·983	0·395	0·037	30·23
3	1950	Sept. 1	Hamilton Inlet Bank	55°20′	55°43′	180–179	329–327	3·52	–	18·75	77·68	3·57	112	29·848	0·449	0·042	35·27
4	1952	Sept. 20	„ „ „	54°51′	53°58′	204	373	3·25	0·86	–	92·24	6·90	116	30·052	0·319	0·030	33·78
5	1954	Sept. 19	„ „ „	54°50′	53°43′	300	549	3·92	–	1·72	97·41	0·86	116	29·991	0·161	0·015	39·07
6	1951	Sept. 19	„ „ „	54°35′	53°51′	155–160	284–293	3·51	0·87	0·87	90·43	7·83	115	30·052	0·347	0·032	27·62
7	1953	Sept. 16	„ „ „	54°08′	53°16′	164–170	300–311	3·10	–	3·23	93·55	3·23	62	30·000	0·256	0·033	33·08
8	1951	Sept. 23	NE Nfld. Shelf	52°46′	53°09′	132–104	241–190	2·10	–	53·85	46·15	–	117	29·462	0·501	0·046	33·83
9	1950	Sept. 27	„ „	51°57′	53°51′	175	320	1·29	–	40·83	59·17	–	120	29·592	0·494	0·045	38·54
10	1950	Sept. 23	„ „	51°54′	51°09′	160–163	293–298	3·35	–	76·52	23·48	–	115	29·235	0·426	0·040	34·09
11	1952	Sept. 2	„ „	50°55′	53°26′	172–163	315–298	1·29	0·86	50·00	49·14	–	116	29·483	0·519	0·048	33·50
12	1952	Sept. 4	„ „	50°38′	53°38′	200–192	366–351	2·35	–	38·01	61·98	–	121	29·620	0·487	0·044	36·32
13	1951	Nov. 1	Badger Bay	49°25′	55°39′	155–160	284–293	0·12	–	–	92·92	7·08	113	30·071	0·258	0·024	28·97
14	1950	July 25	NE Cape Bonavista	49°43′	50°44′	175	320	3·11	–	–	95·73	4·27	117	30·043	0·203	0·019	28·76
15	1950	July 27	„ „	48°57′	52°30′	181–173	331–316	2·01	–	41·67	58·33	–	120	29·583	0·495	0·045	38·88
16	1953	Nov. 23	Trinity Bay	48°09′	53°03′	146–188	267–344	0·78	0·89	8·04	84·82	6·25	112	29·964	0·423	0·040	27·06
17	1953	Dec. 3	„ „	47°49′	53°39′	180	329	0·57	–	29·66	66·95	3·39	118	29·737	0·514	0·047	28·81
18	1950	June 26	Off NE Grand Bank	48°05′	48°30′	182–184	333–337	2·43	–	76·27	23·73	–	118	29·237	0·427	0·039	38·20
19	1950	July 14	W Flemish Cap	47°03′	45°40′	160–158	293–289	3·60	–	70·59	28·57	0·84	119	29·303	0·479	0·044	35·70
20	1949	Aug. 29	Flemish Cap	47°09′	45°07′	109–116	199–212	3·75	–	–	87·72	12·28	57	30·123	0·331	0·044	43·46
21	1950	July 11	E Flemish Cap	46°59′	44°09′	162–163	296–298	3·54	–	72·27	26·89	0·84	119	29·286	0·472	0·043	34·89
22	1954	July 18	NE Grand Bank	46°41′	47°19′	160	293	2·10	–	93·33	6·67	–	120	29·067	0·250	0·023	35·58
23	1950	June 15	„ „	46°30′	47°19′	170–169	311–309	2·66	–	89·83	10·17	–	118	29·102	0·304	0·028	36·95
24	1951	July 13	E Grand Bank	45°53′	47°51′	180	329	2·17	–	87·90	12·10	–	124	29·121	0·327	0·029	35·11
25	1951	July 12	„ „	45°05′	48°55′	172–188	315–344	3·10	–	83·74	16·26	–	123	29·163	0·371	0·033	34·28
26	1953	Sept. 14	ESE Grand Bank	43°55′	48°57′	175–155	320–284	–	–	76·72	23·28	–	116	29·233	0·424	0·039	30·18
27	1951	May 4-10	SE Grand Bank	43°45′	49°15′	135–240	247–439	–	–	77·87	22·13	–	122	29·221	0·417	0·038	32·06
28	1949	Dec. 10	„ „	43°05′	49°40′	115–200	210–366	–	–	79·82	20·18	–	114	29·202	0·403	0·038	30·19
29	1951	May 12	S Grand Bank	42°56′	50°40′	200–210	366–384	4·16	–	72·13	27·87	–	122	29·279	0·450	0·041	32·66
30	1947	Sept. 15	SW Grand Bank	43°34′	51°49′	109	199	0·15	1·92	92·31	5·77	–	104	29·038	0·276	0·027	27·98
31	1953	July 17	„ „	44°03′	52°37′	230–360	421–658	–	–	11·86	74·58	13·56	59	30·017	0·508	0·066	33·68
32	1947	Sept. 14	„ „	43°52′	52°31′	115–95	210–174	3·35	–	86·96	13·04	–	92	29·130	0·339	0·035	27·40
33	1947	May 27	„ „	43°54′	52°25′	105–80	192–146	7·32	2·00	88·00	10·00	–	50	29·080	0·340	0·048	27·62
34	1948	Apr. 13	„ „	44°06′	52°28′	57–85	104–155	1·30	0·97	82·52	16·50	–	103	29·155	0·390	0·038	27·36
35	1948	Jan. 6-11	„ „	44°00′	52°00′	50	91	–	–	78·57	21·43	–	98	29·214	0·412	0·042	31·61
36	1947	May 19	„ „	44°17′	51°57′	45	82	3·30	1·16	83·72	15·12	–	86	29·140	0·381	0·041	28·60
37	1953	July 18	„ „	44°16′	52°46′	138–150	252–274	4·78	–	89·09	10·91	–	110	29·109	0·313	0·030	23·92
38	1947	June 24	„ „	44°36′	52°50′	50	91	3·00	–	54·17	45·83	–	48	29·458	0·504	0·073	30·85
39	1947	July 5	„ „	44°44′	53°05′	53	97	–	–	55·36	44·64	–	56	29·446	0·502	0·067	31·21
40	1948	May 4	Halibut Channel	45°10′	55°12′	70–90	128–165	7·62	–	35·90	61·54	2·56	39	29·667	0·530	0·085	39·74
41	1951	May 31	St. Pierre Bank	45°03′	56°12′	148	271	4·34	–	82·20	17·80	–	118	29·178	0·384	0·035	24·18
42	1947	Sept. 5	„ „	45°47′	56°49′	95–112	174–205	–	0·97	83·50	15·53	–	103	29·146	0·381	0·038	28·35
43	1947	Nov. 27	Fortune Bay	47°11′	55°48′	98–102	179–187	0·70	–	90·00	10·00	–	80	29·100	0·302	0·034	25·85
44	1947	Aug. 7	„ „	47°16′	55°42′	107	196	0·10	–	86·52	13·48	–	89	29·135	0·343	0·036	27·83

Sample number	Year	Month	Locality	Position		Depth		Bottom temp. °C	Vertebral frequency (%)				Total fish	Vert. av.	Stand. dev.	Stand. error	Av. fish length*
				Lat. N	Long. W	fath.	m		28	29	30	31					cm
45	1952	Dec. 6	Fortune Bay	47°16′	55°40′	100–102	183–187	–	–	81·60	18·40	–	125	29·184	0·389	0·035	24·86
46	1952	Dec. 6	” ”	47°13′	55°45′	100	183	0·90	1·11	89·44	9·44	–	180	29·083	0·315	0·023	27·08
47	1947	Nov. 28	” ”	47°34′	54°59′	110–120	201–220	0·37	0·92	71·56	27·52	–	109	29·266	0·464	0·044	29·81
48	1947	Aug. 6	Hermitage Bay	47°33′	56°03′	115	210	4·90	–	53·47	41·58	4·95	101	29·515	0·594	0·059	32·47
49	1947	Oct. 3	” ”	47°37′	56°01′	105–125	192–229	–	–	9·91	81·08	9·01	111	29·991	0·437	0·041	35·41
50	1947	Oct. 22	” ”	–	–	100	183	–	–	19·33	78·15	2·52	119	29·832	0·438	0·040	35·06
51	1947	Dec. 1	” ”	47°34′	56°02′	120–135	220–247	4·73	–	39·18	57·73	3·09	97	29·639	0·544	0·055	33·19
52	1948	Aug. 20	” ”	47°32′	56°09′	142–152	260–278	4·70	–	2·33	88·37	9·30	86	30·070	0·336	0·036	35·99
53	1953	Dec. 1	” ”	47°35′	56°05′	156–160	285–293	–	–	61·84	38·16	–	76	29·382	0·489	0·056	29·93
54	1953	Dec. 17	” ”	47°34′	56°12′	127–132	232–241	–	0·85	60·17	37·29	1·69	118	29·398	0·541	0·050	26·78
55	1954	June 27	” ”	47°34′	56°07′	148–142	271–260	–	–	42·15	53·72	4·13	121	29·620	0·567	0·052	32·14
56	1954	Sept. 15	” ”	47°35′	56°10′	143–128	262–234	–	1·77	43·36	52·21	2·65	113	29·558	0·582	0·055	30·15
57	1947	Nov. 13	Ramea	47°33′	57°28′	110	201	1·80	–	87·90	12·10	–	124	29·121	0·327	0·029	32·93
58	1947	July 20	”	47°33′	57°25′	90–112	165–205	–	1·03	85·57	13·40	–	97	29·124	0·361	0·037	31·57
59	1947	Aug. 5	”	47°33′	57°25′	115	210	1·00	–	83·33	16·67	–	102	29·167	0·375	0·037	31·42
60	1947	Nov. 13	Rose Blanche Bank	47°26′	58°05′	125–128	229–234	4·55	–	76·60	23·40	–	94	29·234	0·426	0·044	29·53
61	1947	July 31	Rose Blanche Bank	47°29′	58°34′	115	210	4·60	–	80·52	19·48	–	77	29·195	0·399	0·045	33·12
62	1947	Nov. 12	” ”	47°24′	58°49′	120	220	1·68	–	74·42	25·58	–	86	29·256	0·439	0·047	32·66
63	1953	Nov. 8	Off St. George’s Bay	48°11′	59°56′	180	329	5·44	–	10·57	87·80	1·63	123	29·911	0·339	0·031	28·49
64	1953	Nov. 8	” ”	48°20′	59°46′	140	256	5·60	0·85	68·64	29·66	0·85	118	29·305	0·498	0·046	30·62
65	1949	Nov. 22	Port Saunders	50°45′	57°25′	125	229	–	–	35·14	59·46	5·41	111	29·703	0·566	0·054	35·40
66	1947	Nov. 6	” ”	50°46′	57°25′	89–110	163–201	0·22	–	54·74	41·05	4·21	95	29·495	0·581	0·060	34·77
67	1948	Aug. 11	” ”	50°44′	57°27′	110–120	201–220	3·63	–	8·16	89·80	2·04	98	29·939	0·315	0·032	36·05
68	1950	Oct. 19	” ”	50°20′	58°25′	135–126	247–230	3·57	–	26·89	69·75	3·36	119	29·765	0·499	0·046	34·74
69	1954	Nov. 7	E of Anticosti	49°16′	59°50′	158	289	–	–	1·72	96·55	1·72	116	30·000	0·187	0·017	32·01
70	1950	Oct. 24	” ”	49°27′	60°01′	123–127	225–232	4·28	–	27·83	69·57	2·61	115	29·748	0·493	0·046	34·55
71	1954	Nov. 9	N of Anticosti	49°39′	61°54′	147–145	269–265	5·10	–	5·13	91·45	3·42	117	29·983	0·293	0·027	35·93
72	1948	Aug. 16	” ”	49°34′	61°40′	109–112	199–205	–	–	71·29	28·71	–	101	29·287	0·455	0·045	30·44
73	1950	Oct. 25	E of Anticosti	48°52′	60°45′	100–95	183–174	1·34	0·80	2·40	88·80	8·00	125	30·040	0·368	0·033	36·91
74	1950	Nov. 11	E of Gaspé	48°42′	63°14′	118–122	216–223	2·89	–	11·81	83·46	4·72	127	29·929	0·402	0·036	37·57
75	1950	Nov. 9	Off Magdalen Is.	47°47′	60°34′	163	298	4·72	–	5·17	93·10	1·72	116	29·966	0·261	0·024	36·76
76	1952	Nov. 2	Off C. Breton I.	47°10′	60°01′	170–173	311–316	4·86	0·85	38·98	58·47	1·69	118	29·610	0·540	0·050	31·22
77	1952	Nov. 1	” ” ”	46°34′	59°19′	168	307	3·04	–	6·92	87·69	5·38	130	29·985	0·352	0·031	36·85
78	1952	Nov. 9	Misaine Bank	46°04′	58°39′	110	201	4·70	–	83.46	16·54	–	127	29·165	0·373	0·033	23·61
79	1952	Nov. 8	” ”	45°40′	59°02′	130–148	238–271	3·70	0·83	84·30	14·88	–	121	29·140	0·372	0·034	33·95
80	1952	Nov. 8	” ”	45°35′	58°30′	100–110	183–201	3·60	–	83·06	16·94	–	124	29·169	0·377	0·034	27·10
81	1947	Sept. 3	” ”	45°34′	58°00′	120	220	4·90	0·98	89·22	9·80	–	102	29·088	0·318	0·031	31·59
82	1947	Sept. 4	” ”	45°23′	58°06′	110–120	201–220	2·15	0·88	82·46	16·67	–	114	29·158	0·390	0·037	33·61
83	1950	Jan. 16	Canso Bank	45°00′	60°45′	75–95	137–174	–	0·86	88·79	10·34	–	116	29·095	0·322	0·030	26·45
84	1950	Jan. 11	Banquereau	44°20′	59°45′	80–100	146–183	–	–	84·03	15·97	–	119	29·160	0·368	0·034	32·05
85	1950	May 14	”	44°18′	57°58′	65	119	0·83	–	89·26	10·74	–	121	29·107	0·311	0·028	31·02
86	1950	May 12	Sable Island Bank	44°01′	61°29′	68–74	124–135	7·30	–	90·60	9·40	–	117	29·094	0·293	0·027	23·42
87	1953	Apr. 24	Browns Bank	43°00′	65°00′	65–80	119–146	–	1·04	86·46	12·50	–	192	29·115	0·351	0·025	–
88	1950	Feb. 10	Gulf of Maine	42°28′	68°40′	80–90	146–165	–	1·69	93·22	5·08	–	118	29·034	0·259	0·024	29·48
89	1950	Feb. 3	” ”	42°05′	69°05′	85–100	155–183	–	0·82	95·90	3·28	–	122	29·025	0·202	0·018	28·06

* Fish lengths were from the chin, with mouth closed, to the mid-fork of the caudal fin.

averages are usually between 29·1–29·3. Whereas the Hamilton Inlet Bank redfish between Lat. 55° and 54°N have vertebral averages between 30·0 and 30·05, immediately southward across Hawke Channel, between Lat. 53° and 50°N, the vertebral averages are distinctly different, ranging from 29·2 to 29·6, and with few exceptions they continue to decline still further in the Grand Bank and Flemish Cap areas. However, once these areas are reached, in Lat. 48° to 46°N, there is no further decline in the typical vertebral averages, 29·3 to 29·1, neither toward the southern tip of the Grand Bank at Lat. 43°N, nor on the south-western Grand Bank. Five exceptional samples with higher vertebral averages ranging from 29·7 to 30·1 were taken between southern Labrador and Flemish Cap, and will be discussed later.

Another track of declining vertebral numbers leads from Labrador through the Gulf of St. Lawrence southward along the southern edge of the Laurentian Channel, across the Nova Scotian Shelf to the Gulf of Maine. The Gulf of St. Lawrence redfish, typically, have high vertebral averages of between 29·6 and 30·1, but occasionally within the same small locality, or closely adjacent, may be found very significantly different vertebral averages as low as 29·3. The high vertebral averages (30·0) cease abruptly at sample No. 77, at the southern entrance to the Gulf of St. Lawrence, and only a few miles to the east there is a group of 5 distinctly different vertebral averages (Misaine Bank, samples Nos. 78–82) all between 29·1 and 29·2. This pattern continues, with only a slight decrease in the vertebral averages, southward across the Nova Scotian Shelf to the Gulf of Maine where the 2 samples show vertebral averages of 29·0.

The vertebral averages of redfish from St. Pierre Bank and the south coast of Newfoundland are typically between 29·1 and 29·3, resembling those of the Grand Bank and of the northern part of the Nova Scotian Shelf. The many samples from the same small area of Hermitage Bay are exceptional in possessing higher averages ranging between 29·4 and 30·1. Samples from within Hermitage Bay also in many cases have significantly different vertebral numbers.

Additional comparisons, showing exactly the same trends that have been discussed for average vertebral numbers, are seen for percentage of redfish with 30–31 vertebrae (Figure 4) and with 29–28 vertebrae (Figure 5). Actually, as will be noted in Table 1 and Figures 6–7, almost all redfish have either 29 or 30 vertebrae. In Tunugdliarfik Fjord in West Greenland 98 % of the *mentella*-type redfish have 30–31 vertebrae; in Labrador redfish the percentages run between 81 and 99. Similarly high numbers of vertebrae occur in the Gulf of St. Lawrence, in some of the Hermitage Bay samples, in the exceptional samples, already noted, between southern Labrador and Flemish Cap and in one sample from very deep water on the south-western Grand Bank.

In the parts of the area with low vertebral numbers, the percentages of redfish with 30–31 vertebrae vary in most samples from 10 to 30 % on the Grand Bank and Flemish Cap, between 9 and 17 % on the Nova Scotian Shelf, to only 3 to 5 % in the Gulf of Maine (Figure 4).

Redfish with 31 vertebrae are so unevenly distributed in the samples (Figure 6) that this characteristic can, to a considerable degree, act as a tag, when considering the amount of intermingling between redfish populations. Redfish with 31 vertebrae are most common in Labrador, eastward and northward from Hamilton Inlet Bank; in the Gulf of St. Lawrence; in Hermitage Bay; on the south coast of Newfoundland and in the following samples: No. 20, Flemish Cap; No. 13, Badger Bay; No. 16 and 17, Trinity Bay; No. 14, northeast of Cape Bonavista; No. 31, a deep-water sample from south-western Grand Bank; and No. 40, Halibut Channel.

It is reasonably certain that sample No. 20 (12·3 % with 31 vertebrae) consists mainly of *marinus*-type redfish, and that there are at least some in sample No. 14. The few redfish with 31 vertebrae in Flemish Cap samples No. 19 and 21 may also be *marinus*-type fish, and some were probably present also in the Halibut Channel sample No. 40 (2·6 % with 31 vertebrae). However, for sample No. 31 (13·6 % with 31 vertebrae) the evidence (later presented) indicates that it consists of *mentella*-type redfish of larger size, greater age and from a greater depth than neighbouring samples which contained no fish with 31 vertebrae. There is also evidence that the great majority of redfish in the remaining samples are of the *mentella* type.

From the distribution of redfish with 31 vertebrae (Figure 6) there is no evidence of migration of adult redfish or of redfish larvae southward from the Hamilton Inlet Bank area across Hawke Channel or eastward from the Gulf of St.Lawrence over the Northeast Newfoundland Shelf. The adult *mentella*-type redfish of the Gulf of St. Lawrence could not migrate eastward through the Strait of Belle Isle in any case, since the Strait is too shallow, but redfish larvae and fry could be expected to pass outward with the surface current on the eastern side of the Strait. Similarly there is no evidence of movement of adult, or larval, redfish from the Gulf of St. Lawrence out along the Laurentian Channel between St.Pierre Bank and the Nova Scotian Shelf, or from the Gulf over or around the Nova Scotian Shelf. Yet it is to be expected, unless such larvae are blown by the prevailing W and SW winds towards St. Pierre Bank and the western part of the south coast of Newfoundland, that they would be carried by the Cape Breton Current from the Gulf,

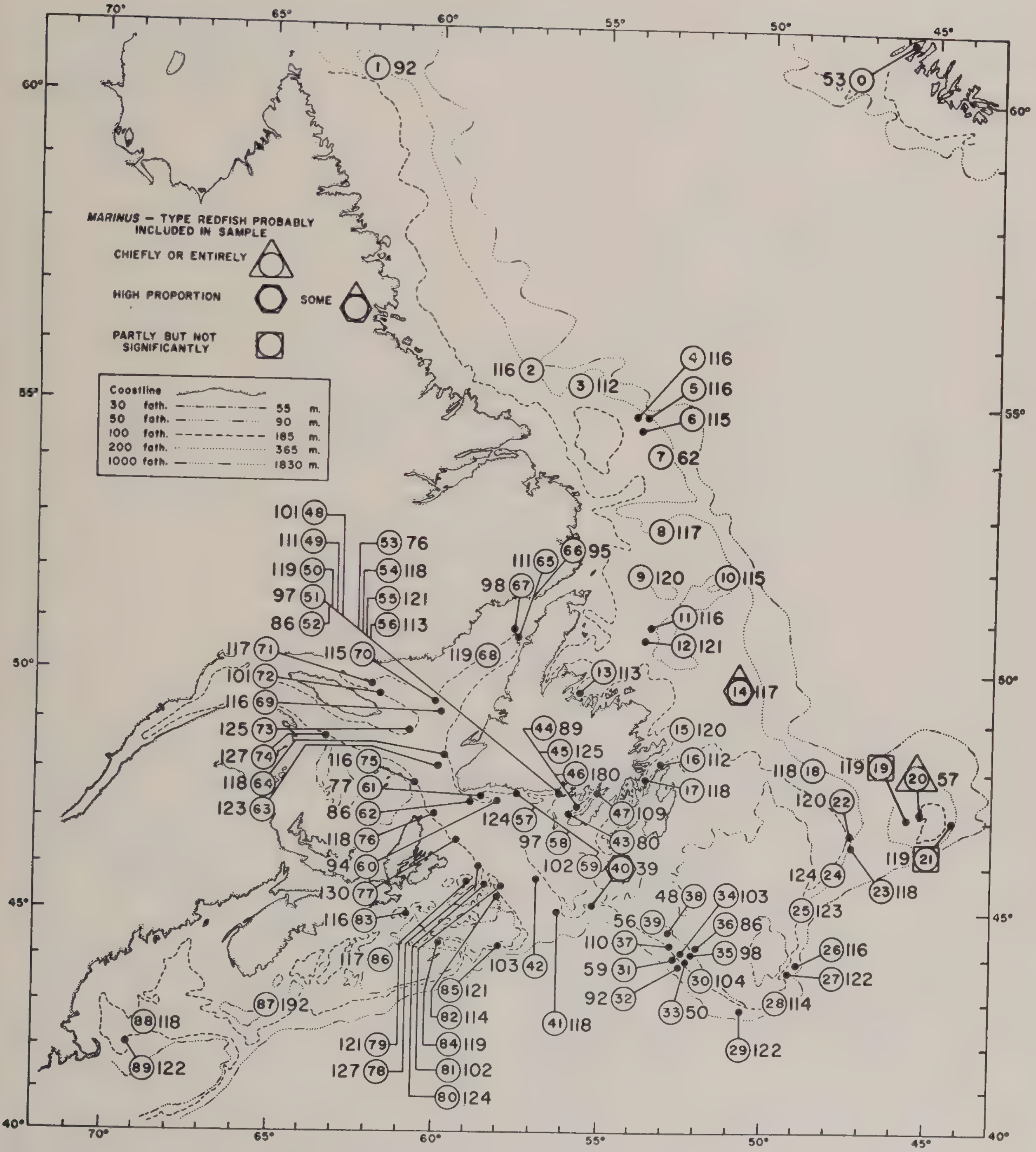

70°
65°
60°
55°
50°
45°
40°
MARINUS – TYPE REDFISH PROBABLY INCLUDED IN SAMPLE
CHIEFLY OR ENTIRELY
HIGH PROPORTION
SOME
PARTLY BUT NOT SIGNIFICANTLY
Coastline
30 fath. 55 m.
50 fath. 90 m.
100 fath. 185 m.
200 fath. 365 m.
1000 fath. 1830 m.
① 92
53 (0)
116 ②
③ 112
④ 116
⑤ 116
⑥ 115
⑦ 62
⑧ 117
⑨ 120
⑩ 115
⑪ 116
⑫ 121
⑬ 113
⑭ 117
⑮ 120
⑯ 112
⑰ 118
118 ⑱
119 ⑲
⑳ 57
120 ㉑
119 ㉑
124 ㉔
㉓ 118
㉕ 123
㉖ 116
㉗ 122
㉘ 114
㉙ 122
㉚ 104
59 ㉛
92 ㉜
㉝ 50
㉞ 103
㉟ 98
㊱ 86
110 ㊲
48 ㊳
56 ㊴
㊵ 39
㊶ 118
103 ㊷
㊸ 80
㊹ 89
㊺ 125
㊻ 180
㊼ 109
101 ㊽
111 ㊾
119 ㊿
97 (51)
86 (52)
(53) 76
(54) 118
(55) 121
(56) 113
124 (57)
97 (58)
102 (59)
94 (60)
77 (61)
86 (62)
123 (63)
118 (64)
111 (65)
(66) 95
98 (67)
119 (68)
116 (69)
115 (70)
117 (71)
101 (72)
125 (73)
127 (74)
116 (75)
118 (76)
130 (77)
127 (78)
121 (79)
(80) 124
(81) 102
(82) 114
116 (83)
(84) 119
(85) 121
117 (86)
(87) 192
(88) 118
(89) 122

Figure 2. Numbers of redfish (outside circles) and vertebral columns of the samples considered in the text. In this figure and also in Figures 3–7, the number of the sample (see Table 1 for further details) is in a circle and the centre of the circle marks the position from which the sample was taken except where the position is marked by a black dot.

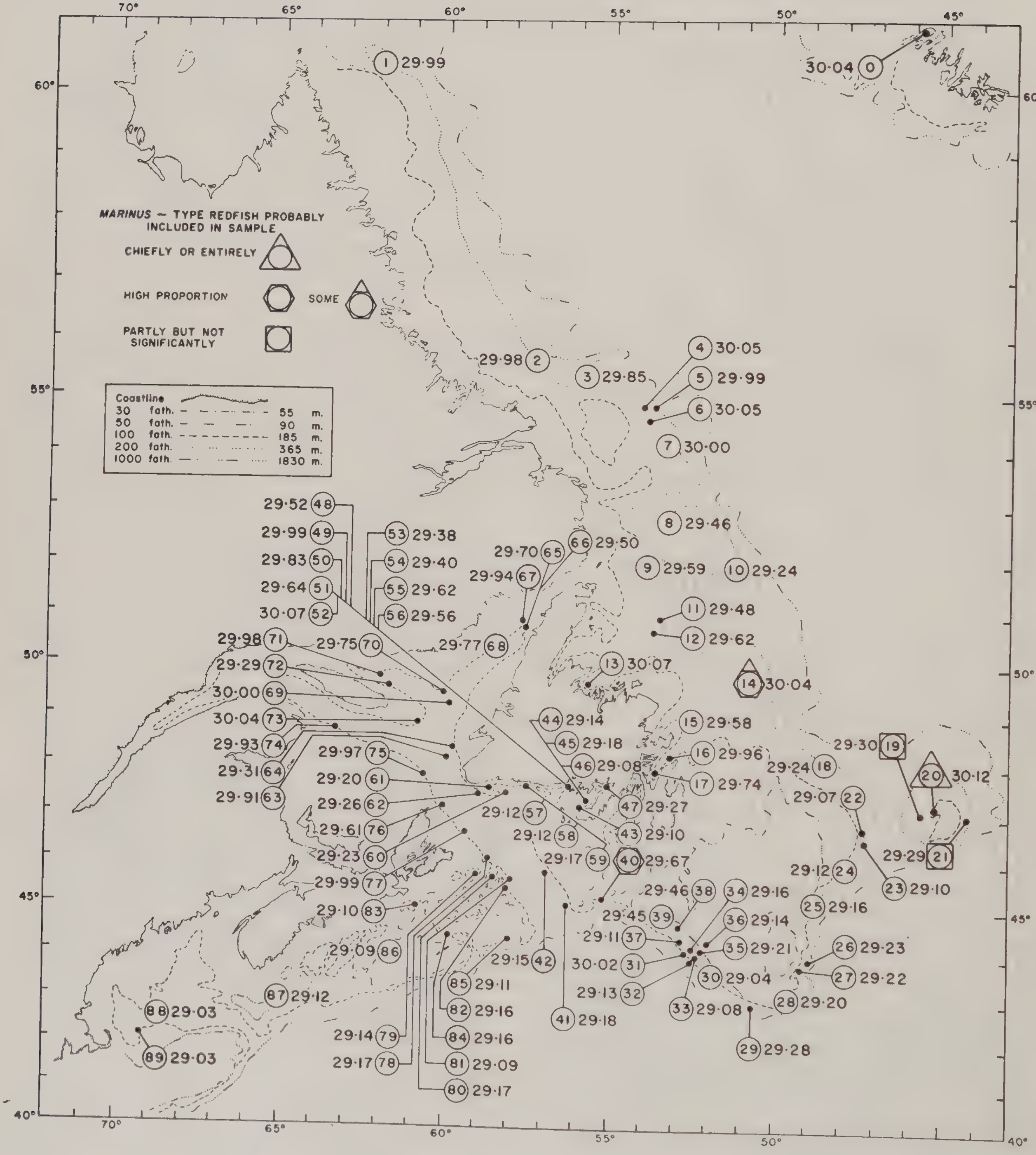

70°
65°
60°
55°
50°
45°
40°
MARINUS — TYPE REDFISH PROBABLY INCLUDED IN SAMPLE
CHIEFLY OR ENTIRELY
HIGH PROPORTION
SOME
PARTLY BUT NOT SIGNIFICANTLY
Coastline
30 fath. 55 m.
50 fath. 90 m.
100 fath. 185 m.
200 fath. 365 m.
1000 fath. 1830 m.
30·04 (0)
(1) 29·99
29·98 (2)
(3) 29·85
(4) 30·05
(5) 29·99
(6) 30·05
(7) 30·00
(8) 29·46
(9) 29·59
(10) 29·24
(11) 29·48
(12) 29·62
(13) 30·07
(14) 30·04
(15) 29·58
(16) 29·96
(17) 29·74
29·24 (18)
29·30 (19)
(20) 30·12
29·29 (21)
29·07 (22)
(23) 29·10
29·12 (24)
(25) 29·16
(26) 29·23
(27) 29·22
(28) 29·20
(29) 29·28
(30) 29·04
30·02 (31)
29·13 (32)
(33) 29·08
(34) 29·16
(35) 29·21
(36) 29·14
29·11 (37)
29·46 (38)
29·45 (39)
(40) 29·67
(41) 29·18
29·15 (42)
(43) 29·10
(44) 29·14
(45) 29·18
(46) 29·08
(47) 29·27
29·52 (48)
29·99 (49)
29·83 (50)
29·64 (51)
30·07 (52)
(53) 29·38
(54) 29·40
(55) 29·62
(56) 29·56
29·12 (57)
29·12 (58)
29·17 (59)
29·23 (60)
29·20 (61)
29·26 (62)
29·91 (63)
29·31 (64)
29·70 (65)
(66) 29·50
29·94 (67)
29·77 (68)
30·00 (69)
29·75 (70)
29·98 (71)
29·29 (72)
30·04 (73)
29·93 (74)
29·97 (75)
29·61 (76)
29·99 (77)
29·17 (78)
29·14 (79)
(80) 29·17
(81) 29·09
(82) 29·16
29·10 (83)
(84) 29·16
(85) 29·11
29·09 (86)
(87) 29·12
(88) 29·03
(89) 29·03

Figure 3. Average vertebral number in redfish samples.

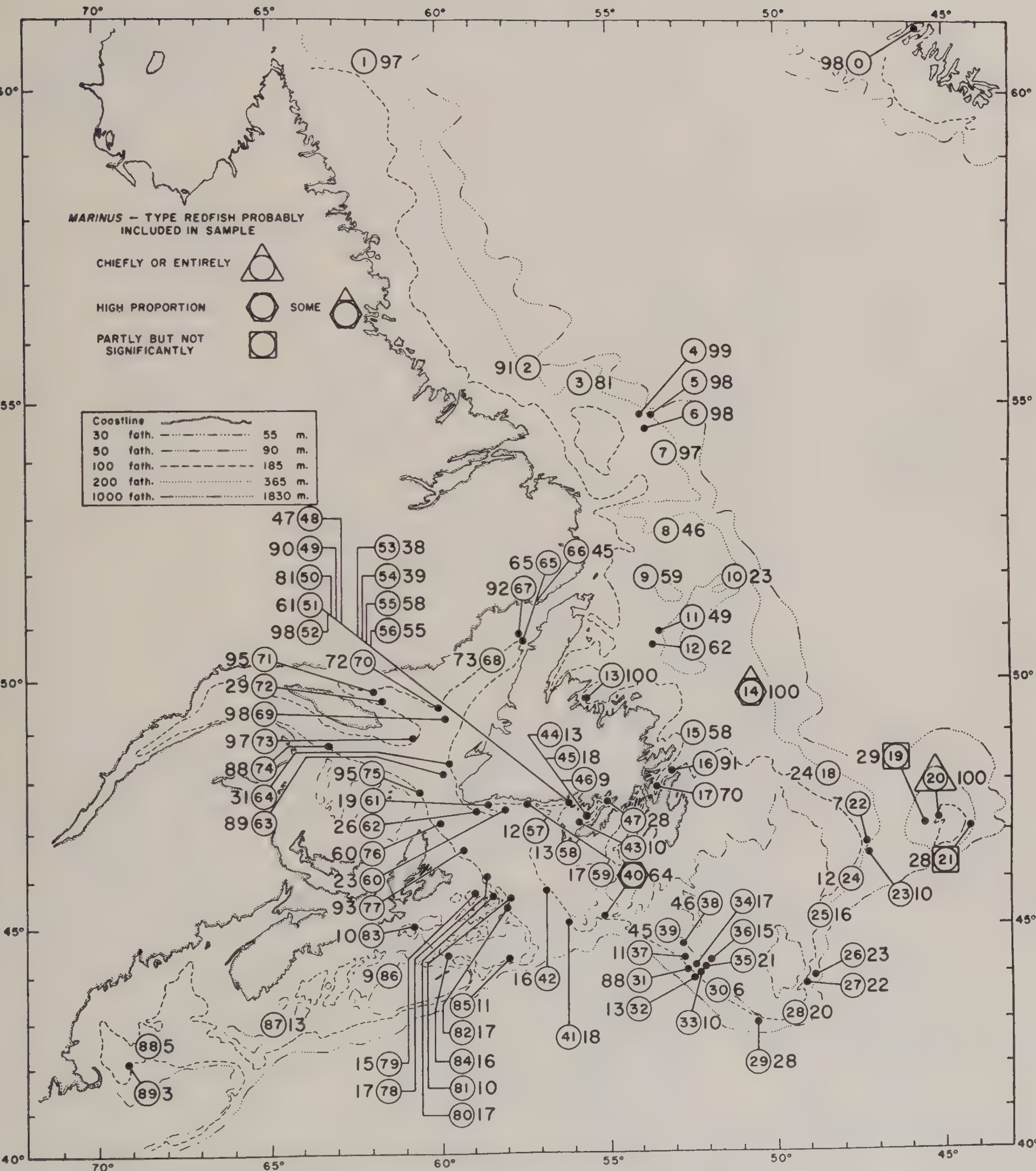
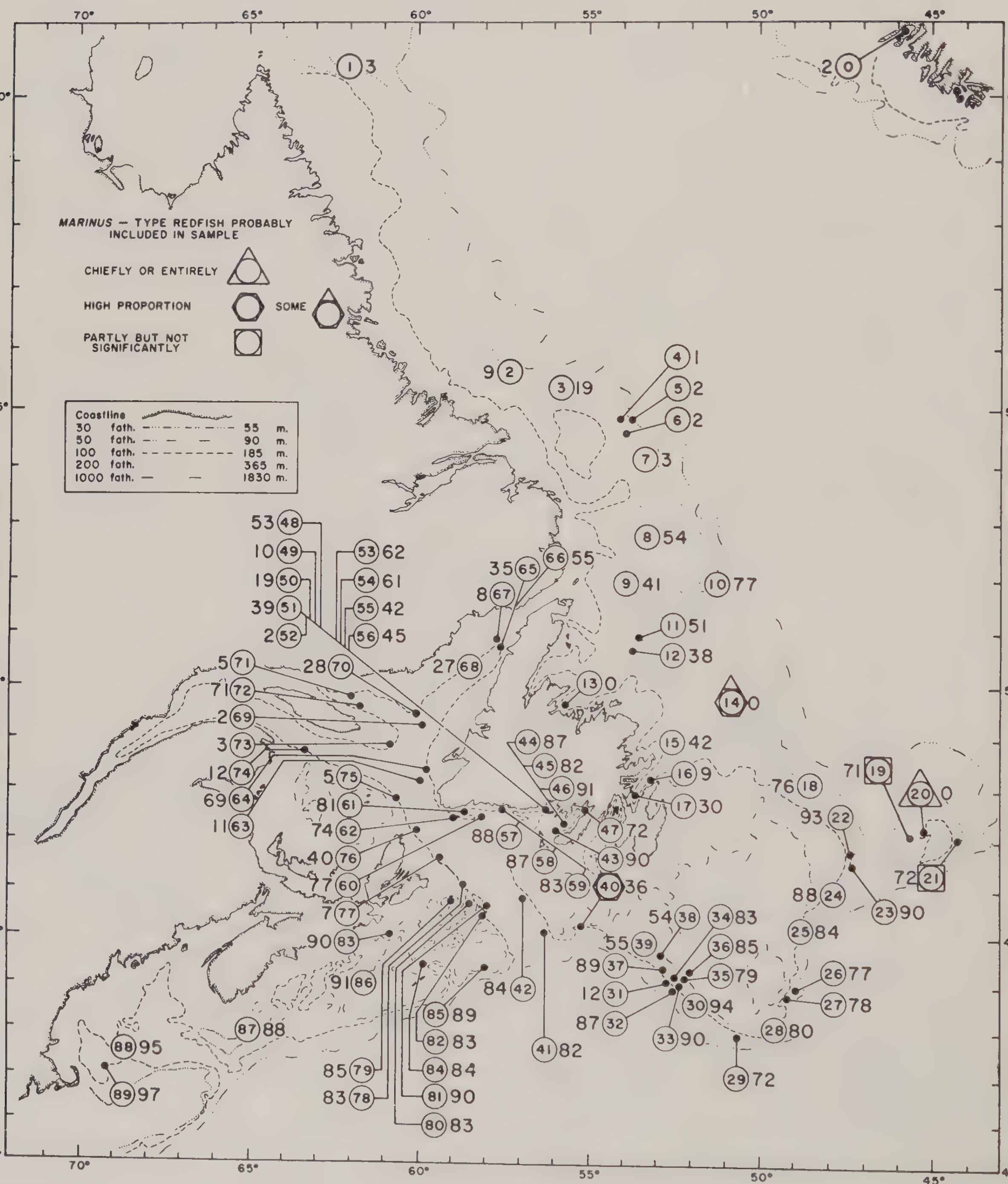

70°
65°
60°
55°
50°
45°
60°
55°
50°
45°
40°
MARINUS – TYPE REDFISH PROBABLY INCLUDED IN SAMPLE
CHIEFLY OR ENTIRELY
HIGH PROPORTION
SOME
PARTLY BUT NOT SIGNIFICANTLY
Coastline
30 fath. 55 m.
50 fath. 90 m.
100 fath. 185 m.
200 fath. 365 m.
1000 fath. 1830 m.
① 97
98 ⓪
91 ②
③ 81
④ 99
⑤ 98
⑥ 98
⑦ 97
⑧ 46
⑨ 59
⑩ 23
⑪ 49
⑫ 62
⑬ 100
⑭ 100
⑮ 58
⑯ 91
⑰ 70
24 ⑱
29 ⑲
⑳ 100
28 ㉑
7 ㉒
㉓ 10
12 ㉔
㉕ 16
㉖ 23
㉗ 22
㉘ 20
㉙ 28
㉚ 6
88 ㉛
13 ㉜
㉝ 10
㉞ 17
㉟ 21
㊱ 15
11 ㊲
46 ㊳
45 ㊴
㊵ 64
㊶ 18
16 ㊷
㊸ 10
㊹ 13
㊺ 18
㊻ 9
㊼ 28
47 ㊽
90 ㊾
81 ㊿
61 (51)
98 (52)
(53) 38
(54) 39
(55) 58
(56) 55
12 (57)
13 (58)
17 (59)
23 (60)
19 (61)
26 (62)
89 (63)
31 (64)
65 (65)
(66) 45
92 (67)
73 (68)
98 (69)
72 (70)
95 (71)
29 (72)
97 (73)
88 (74)
95 (75)
60 (76)
93 (77)
17 (78)
15 (79)
(80) 17
(81) 10
(82) 17
10 (83)
(84) 16
(85) 11
9 (86)
(87) 13
(88) 5
(89) 3

Figure 4. Percentages of redfish with 30–31 vertebrae.


70°
65°
60°
55°
50°
45°
60°
55°
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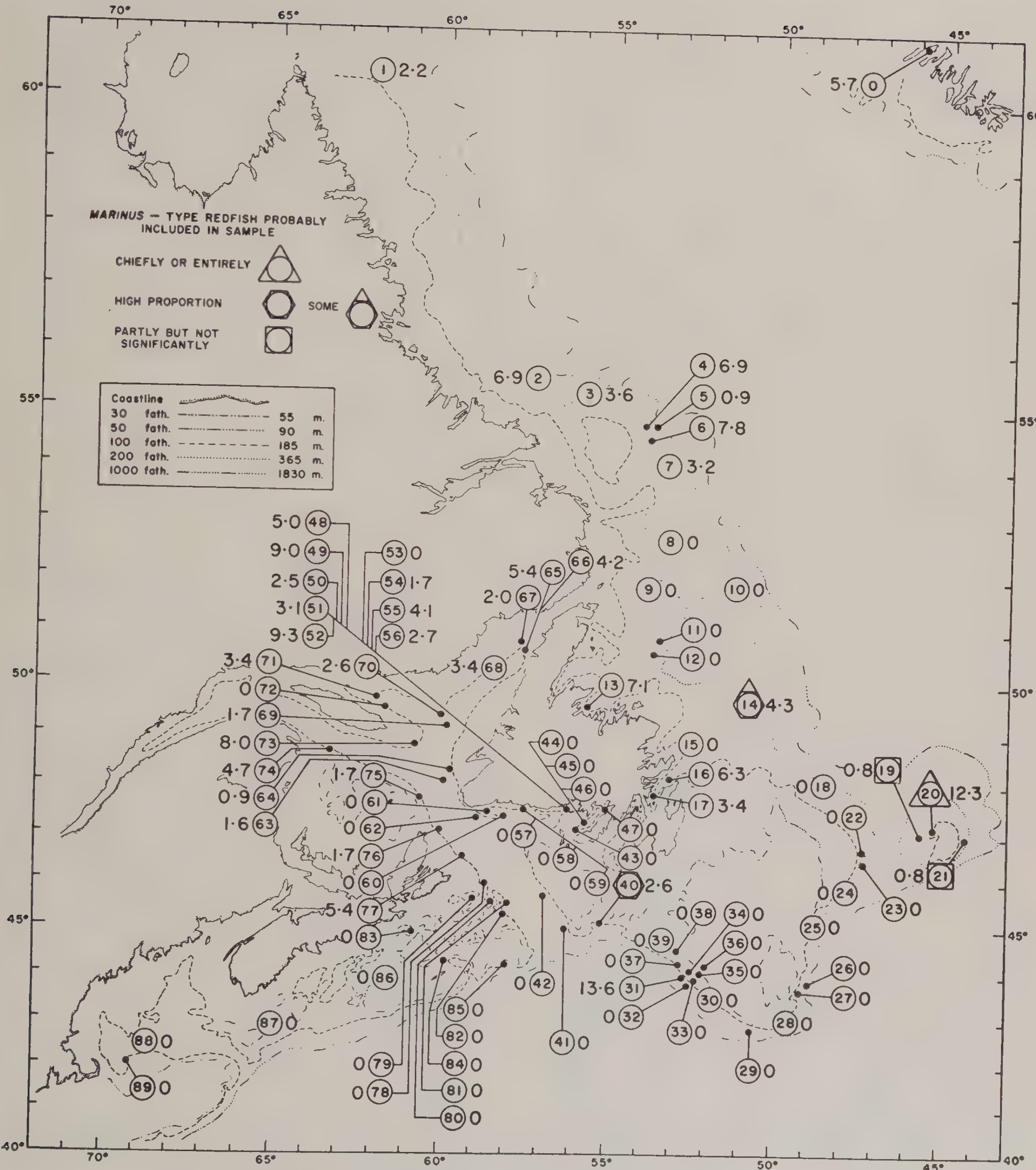
45°
40°
MARINUS — TYPE REDFISH PROBABLY INCLUDED IN SAMPLE
CHIEFLY OR ENTIRELY
HIGH PROPORTION
SOME
PARTLY BUT NOT SIGNIFICANTLY
Coastline
30 fath. 55 m.
50 fath. 90 m.
100 fath. 185 m.
200 fath. 365 m.
1000 fath. 1830 m.
(1) 3
2 (0)
9 (2)
(3) 19
(4) 1
(5) 2
(6) 2
(7) 3
(8) 54
(9) 41
(10) 77
(11) 51
(12) 38
(13) 0
(14) 0
(15) 42
(16) 9
(17) 30
76 (18)
71 (19)
(20) 0
72 (21)
93 (22)
(23) 90
88 (24)
(25) 84
(26) 77
(27) 78
(28) 80
(29) 72
(30) 94
12 (31)
87 (32)
(33) 90
(34) 83
(35) 79
(36) 85
89 (37)
54 (38)
55 (39)
(40) 36
(41) 82
84 (42)
(43) 90
(44) 87
(45) 82
(46) 91
(47) 72
53 (48)
10 (49)
19 (50)
39 (51)
2 (52)
(53) 62
(54) 61
(55) 42
(56) 45
88 (57)
87 (58)
83 (59)
77 (60)
81 (61)
74 (62)
11 (63)
69 (64)
35 (65)
(66) 55
8 (67)
27 (68)
2 (69)
28 (70)
5 (71)
71 (72)
3 (73)
12 (74)
5 (75)
40 (76)
7 (77)
83 (78)
85 (79)
(80) 83
(81) 90
(82) 83
90 (83)
(84) 84
(85) 89
91 (86)
(87) 88
(88) 95
(89) 97

Figure 5. Percentages of redfish with 29–28 vertebrae.


70°
65°
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55°
50°
45°
40°
MARINUS — TYPE REDFISH PROBABLY INCLUDED IN SAMPLE
CHIEFLY OR ENTIRELY
HIGH PROPORTION
SOME
PARTLY BUT NOT SIGNIFICANTLY
Coastline
30 fath. 55 m.
50 fath. 90 m.
100 fath. 185 m.
200 fath. 365 m.
1000 fath. 1830 m.
1 2·2
5·7 0
6·9 2
3 3·6
4 6·9
5 0·9
6 7·8
7 3·2
8 0
9 0
10 0
11 0
12 0
13 7·1
14 4·3
15 0
16 6·3
17 3·4
0 18
0·8 19
20 12·3
0·8 21
0 22
23 0
0 24
25 0
26 0
27 0
28 0
29 0
30 0
13·6 31
0 32
33 0
34 0
35 0
36 0
0 37
0 38
0 39
40 2·6
41 0
0 42
43 0
44 0
45 0
46 0
47 0
5·0 48
9·0 49
2·5 50
3·1 51
9·3 52
53 0
54 1·7
55 4·1
56 2·7
0 57
0 58
0 59
0 60
0 61
0 62
1·6 63
0·9 64
5·4 65
66 4·2
2·0 67
3·4 68
1·7 69
2·6 70
3·4 71
0 72
8·0 73
4·7 74
1·7 75
1·7 76
5·4 77
0 78
0 79
80 0
81 0
82 0
0 83
84 0
85 0
0 86
87 0
88 0
89 0

Figure 6. Percentages of redfish with 31 vertebrae.

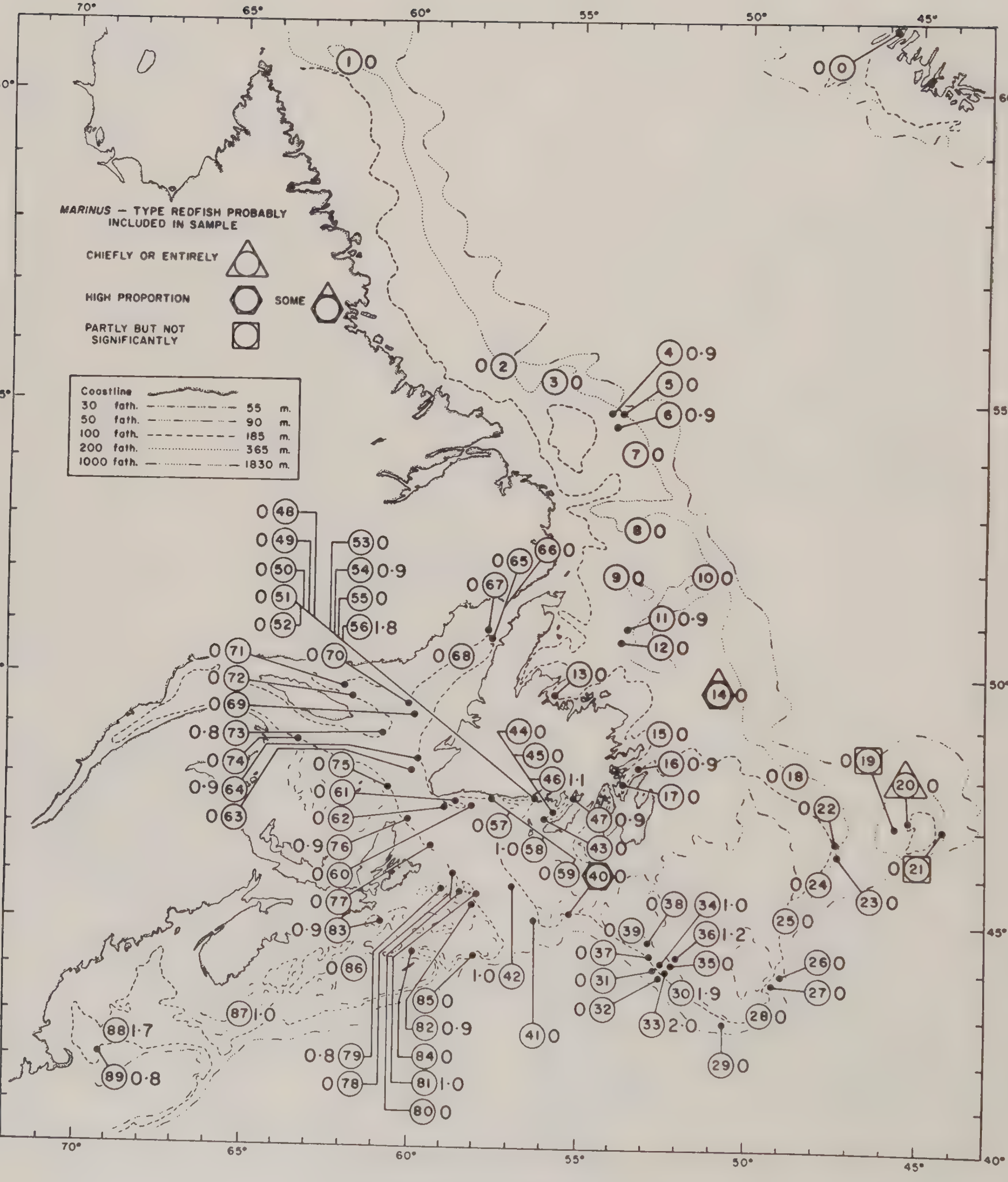
70°
65°
60°
55°
50°
45°
40°
MARINUS – TYPE REDFISH PROBABLY INCLUDED IN SAMPLE
CHIEFLY OR ENTIRELY
HIGH PROPORTION
SOME
PARTLY BUT NOT SIGNIFICANTLY
Coastline
30 fath. 55 m.
50 fath. 90 m.
100 fath. 185 m.
200 fath. 365 m.
1000 fath. 1830 m.
1 0
0 0
0 2
3 0
4 0·9
5 0
6 0·9
7 0
8 0
9 0
10 0
11 0·9
12 0
13 0
14 0
15 0
16 0·9
17 0
0 18
0 19
20 0
0 21
0 22
23 0
0 24
25 0
26 0
27 0
28 0
29 0
30 1·9
0 31
0 32
33 2·0
34 1·0
35 0
36 1·2
0 37
0 38
0 39
40 0
41 0
1·0 42
43 0
44 0
45 0
46 1·1
47 0·9
0 48
0 49
0 50
0 51
0 52
53 0
54 0·9
55 0
56 1·8
0 57
1·0 58
0 59
0 60
0 61
0 62
0 63
0·9 64
0 65
66 0
0 67
0 68
0 69
0 70
0 71
0 72
0·8 73
0 74
0 75
0·9 76
0 77
0 78
0·8 79
80 0
81 1·0
82 0·9
0·9 83
84 0
85 0
0 86
87 1·0
88 1·7
89 0·8

Figure 7. Percentages of redfish with 28 vertebrae.

over the Nova Scotian Shelf. It is evident that to utilize such vertebral number data adequately, more data are required over the whole depth range of the species, so that the distribution of the fish with 31 vertebrae may be compared by depth and fish size and age and by *mentella* and *marinus* type.

There are even fewer redfish in the area with 28 vertebrae (Figure 7) than there are with 31. They are, however, more widely distributed, and a small percentage of these fish occurred occasionally in samples taken over most of the area. For adequate discussion more data are required on the variation in vertebral count throughout the whole depth and size range of each of the *mentella* and *marinus* types of redfish. It is unlikely, however, that the analysis of such data on the presence of 28 vertebrae will be as fruitful for the study of adult migration and larval drift as similar data for redfish with 31 vertebrae.

Vertebral number in relation to fish length and sex

Although otoliths were collected it has not been possible to age most of the large number of redfish in these vertebral samples.

Since these redfish grow very slowly, and females faster than males, analysis of vertebral number by length and sex can, to a considerable degree, take the place of analysis by age, although the latter is desirable also, particularly in order to explain differences in vertebral count in the same area or in different areas in relation to hydrographic conditions.

Figures 8–15 show the relationship between vertebral number and fish length. Neighbouring samples of the same kind are combined and the exceptional samples from an area are usually shown separately.

In Tunugdliarfik Fjord in West Greenland *mentella*-type redfish of all sizes possessed 30–31 vertebrae almost without exception (Table 1).

The Labrador samples (Figure 8) show that most fish of all lengths possess 30–31 vertebrae; this was also true of sample No. 13, Badger Bay; sample No. 14, north-east of Cape Bonavista; samples No. 16–17, Trinity Bay (Figure 8) and sample No. 20, Flemish Cap (Figure 9).

Off the north-east coast of Newfoundland (samples No. 8–12) and north-east of Cape Bonavista (sample No. 15 (Figure 8)) the numbers of redfish at each length with 29–28 or with 30–31 vertebrae are approximately equal, but usually with a tendency for the larger sizes to have the greater number of vertebrae and the smaller sizes the lower.

At Flemish Cap (Nos. 19 and 21 (Figure 8)) redfish with vertebral numbers of 29–28 predominate at all sizes except the very largest, which are too few in number to affect the averages significantly.

The north-eastern Grand Bank, south-eastern and southern Grand Bank, south-western Grand Bank and St. Pierre Bank redfish have predominantly 29–28 vertebrae at almost all sizes. On the south-western Grand Bank the 30–31 vertebral numbers become increasingly important toward the larger sizes and predominate in the few fish of the largest sizes. Similarly, among the few redfish of the largest size on St. Pierre Bank the vertebral numbers 30–31 are predominant (Figure 9).

On the south coast of Newfoundland vertebral numbers 29–28 predominate at all sizes at which there are significant numbers of fish, both in Fortune Bay (Figure 10) and in the Ramea and Rose Blanche samples (Figure 11). In the intermediate area between these two groups, Hermitage Bay (Figure 11), the vertebral group 30–31 predominates at the larger sizes and the 29–28 at the smaller sizes, both in 1947–48 and in 1953–54.

In the Gulf of St. Lawrence as a whole (Figure 14) the larger redfish are predominantly of the 30–31 vertebral group and the smallest redfish of the 29–28. In the individual areas of the Gulf, however, there are departures from the overall pattern. Thus samples Nos. 69–71, 73, from north and east of Anticosti (Figure 11) have vertebral numbers 30–31 predominant at both smaller and larger sizes, whilst in sample No. 72, from north of Anticosti, counts of 29–28 predominate at these same smaller sizes. St. George's Bay (Figure 12) possesses two well-separated length groups, with the 30–31 vertebral group predominating in the larger and the 29–28 vertebral group in the smaller sizes of each length group.

In the Nova Scotian Shelf area, No. 78–86 (Figures 12 and 14) and in the Gulf of Maine (Figure 14) the vertebral group 29–28 predominates at all sizes.

Use of vertebral numbers to dissect and elucidate length-frequencies, and use of length-frequencies to improve the accuracy of vertebral averages

At best, compared with the large numbers of redfish measured at sea, only small numbers of vertebral columns are examined for vertebral number; also, these fish are generally from group samples and are thus only an approximation to a random sample. The much larger numbers of redfish actually measured on board ship or on shore should thus much more closely resemble the actual length-frequency of the population.

Therefore, in a restricted area, Hermitage Bay, from which many redfish were measured, and for which there are moderately large numbers of vertebral counts in relation to fish lengths, the percentages of redfish with various vertebral numbers at different sizes have been calculated and applied to show the distribution of vertebral numbers in the actual frequency (Figure 15). For both the 1947–48 and the 1953–54 periods,

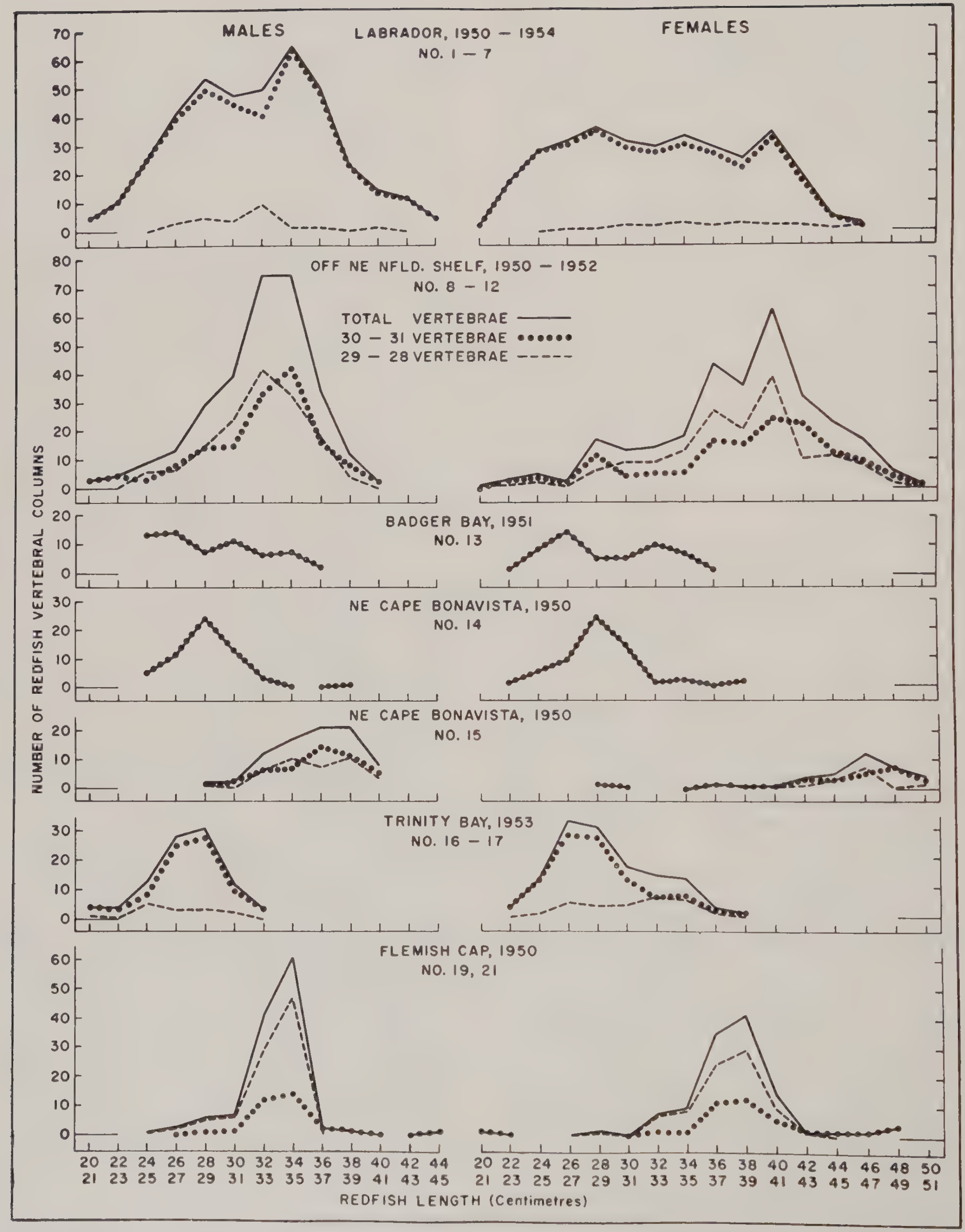

Figure 8. Relation of vertebral number and redfish length (chin to mid-fork of the caudal fin in this and succeeding figures) from Labrador to Flemish Cap.

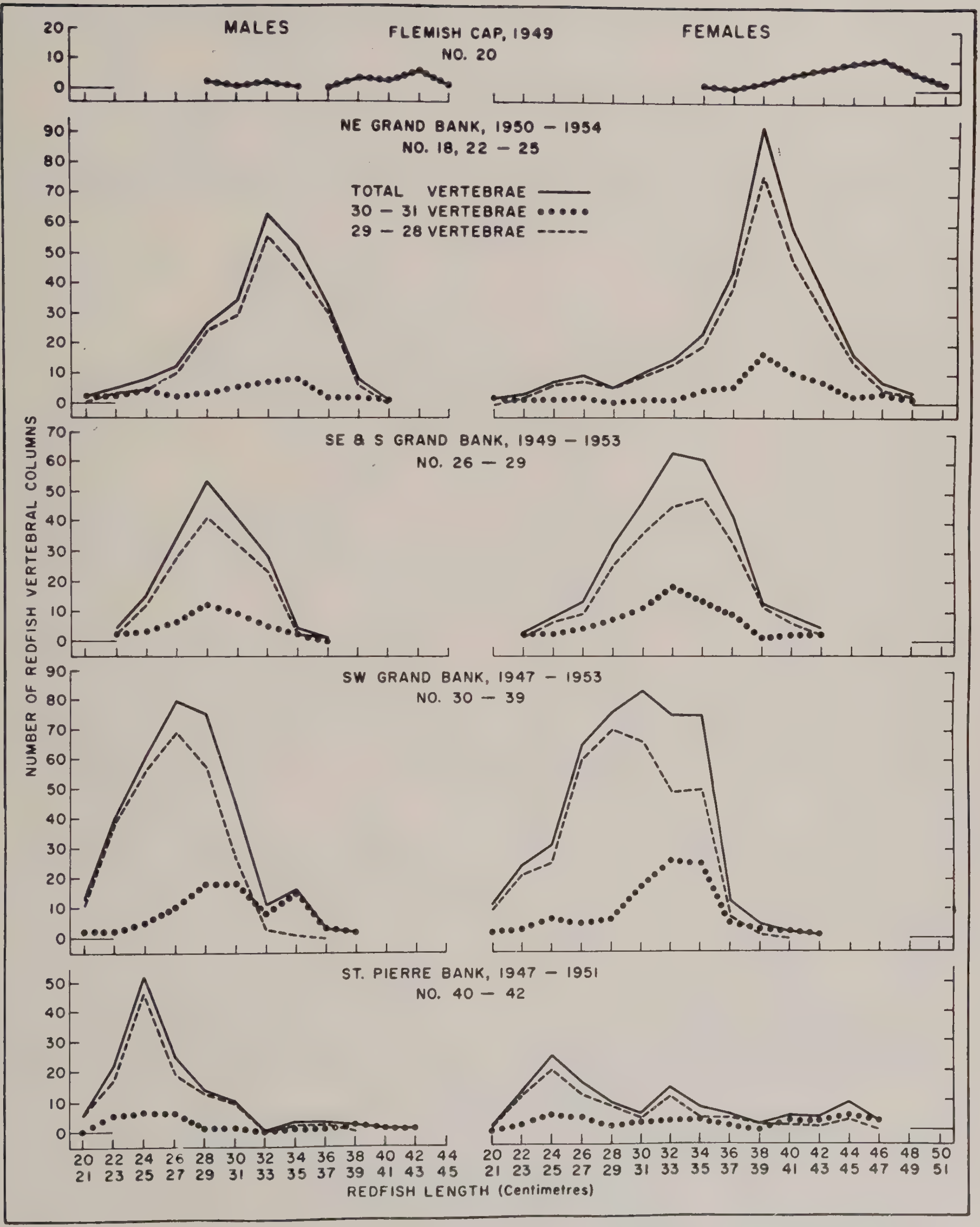

Figure 9. Relation of vertebral number and redfish length from Flemish Cap to St. Pierre Bank.

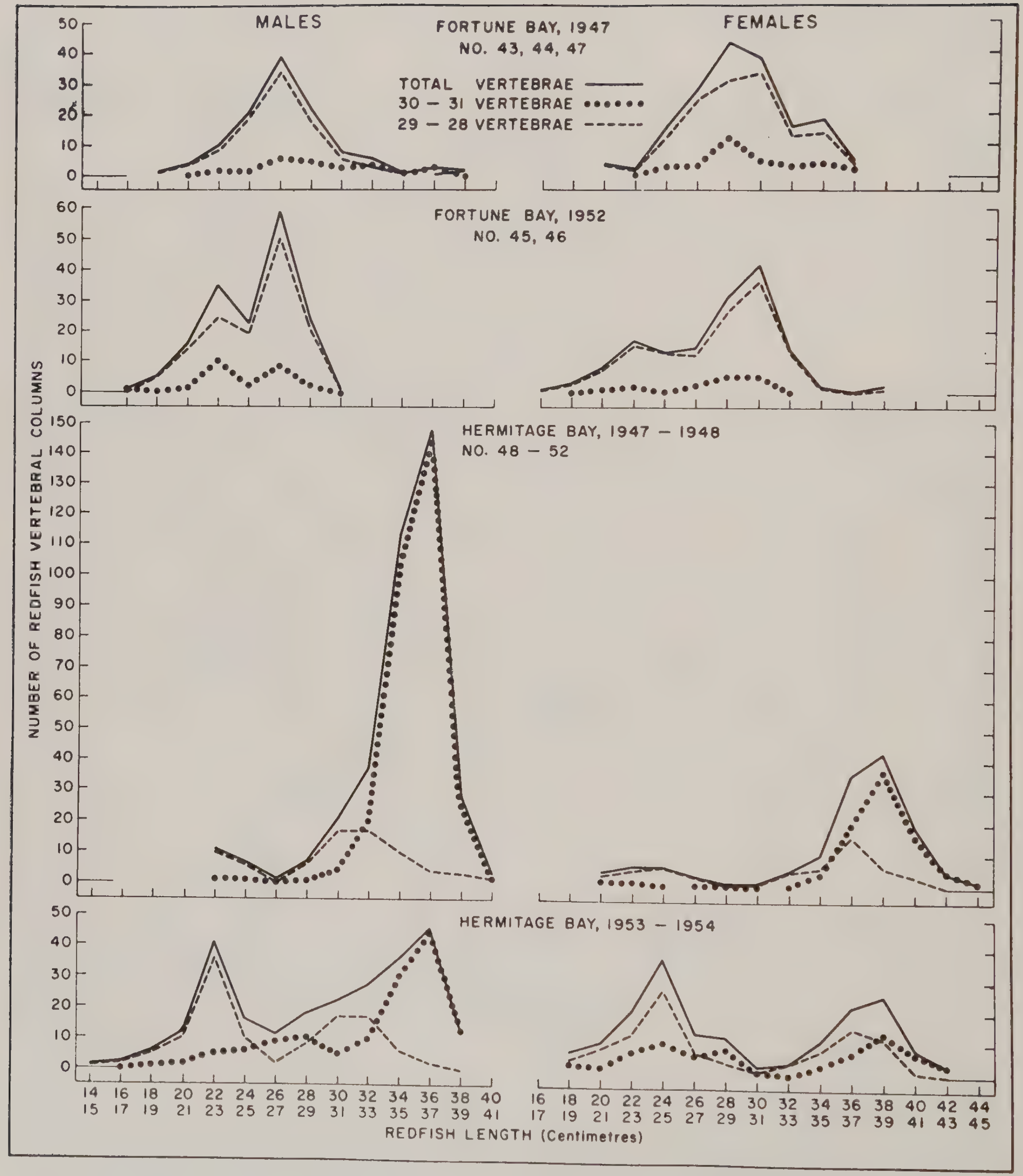

Figure 10. Relation of vertebral number and redfish length from Fortune Bay to Hermitage Bay.

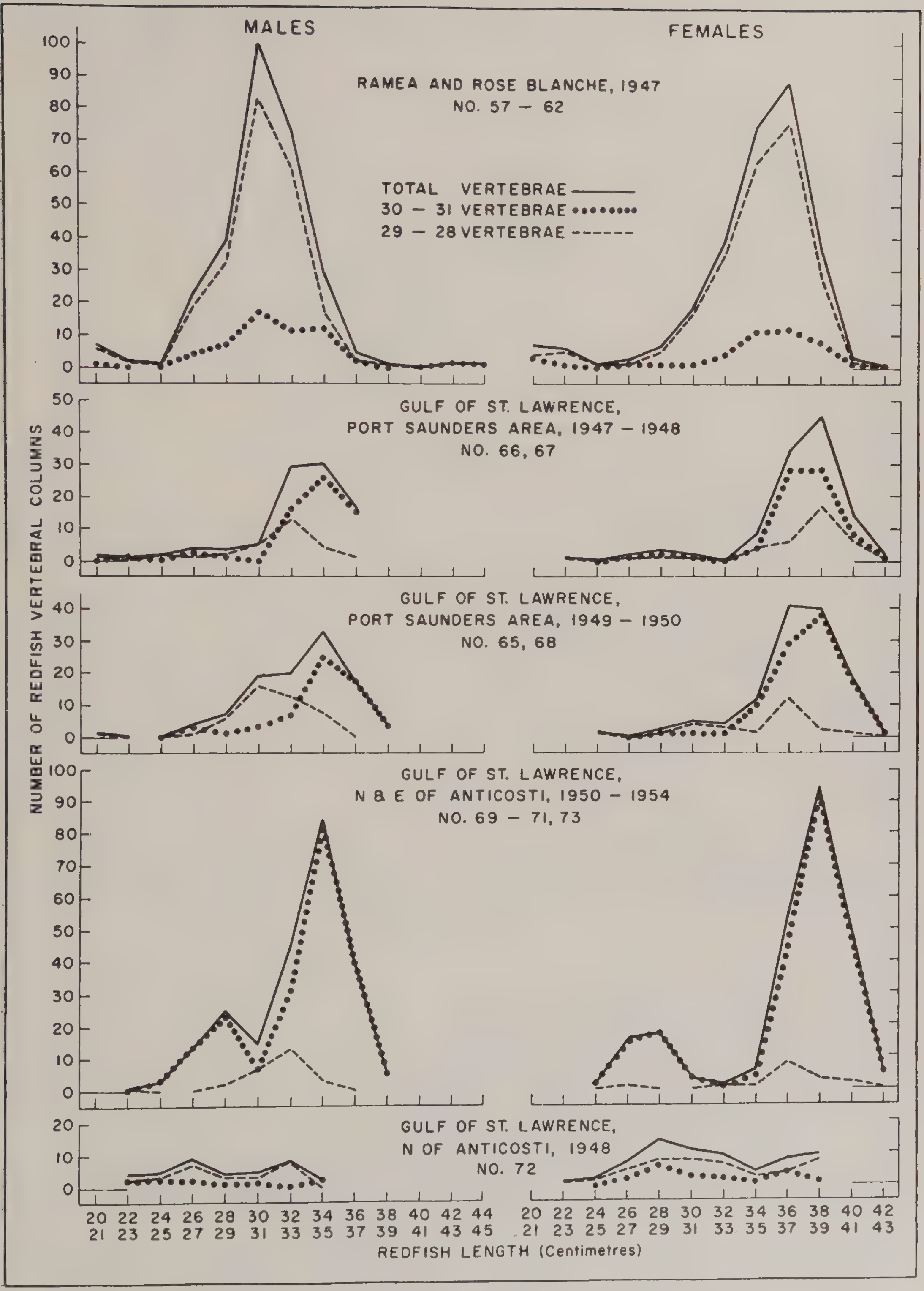

Figure 11. Relation of vertebral number and redfish length from Ramea and Rose Blanche to Gulf of St. Lawrence north of Anticosti.

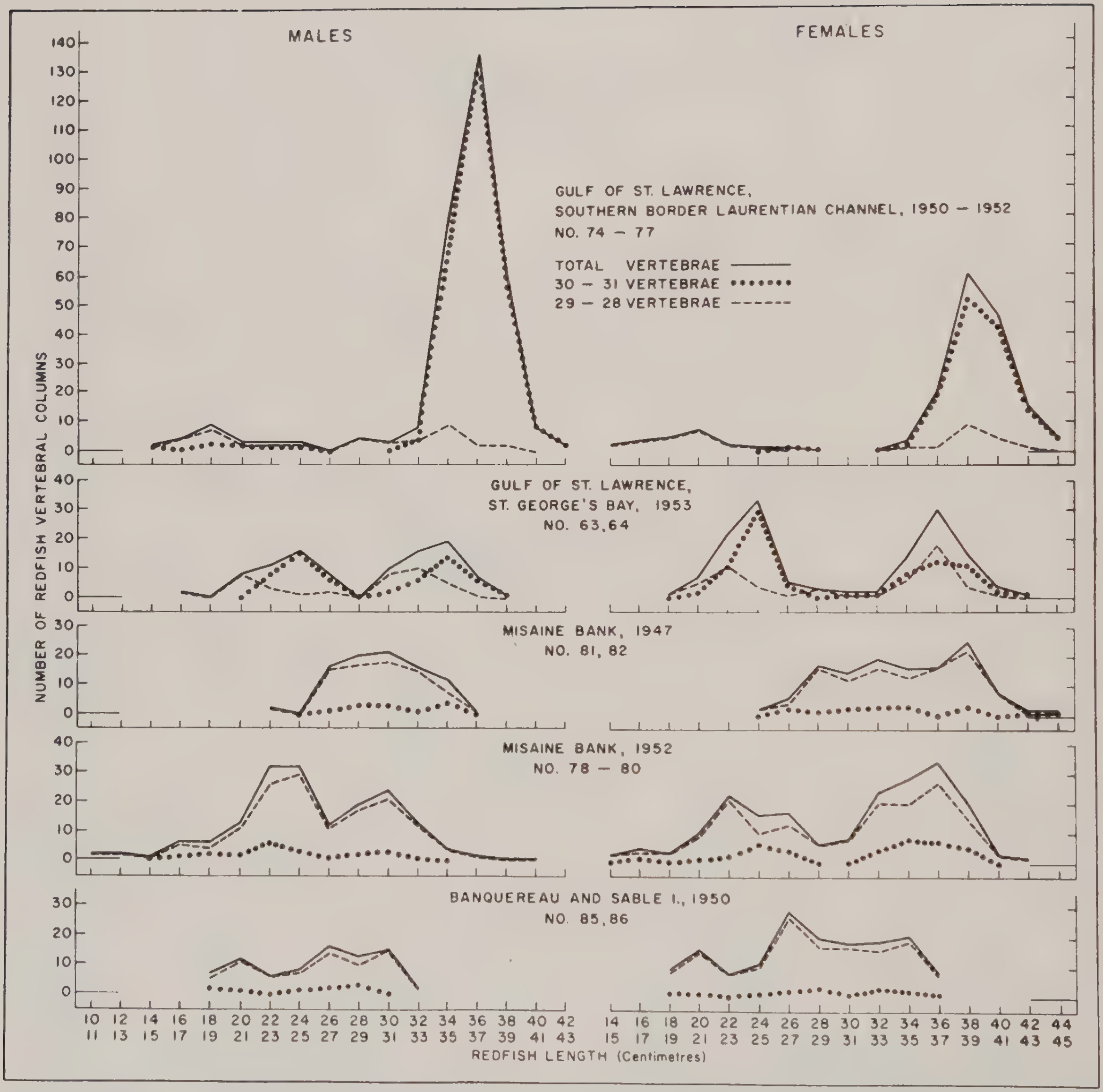

Figure 12. Relation of vertebral number and redfish length from Gulf of St. Lawrence, southern border Laurentian Channel, to Banquereau and Sable Island.

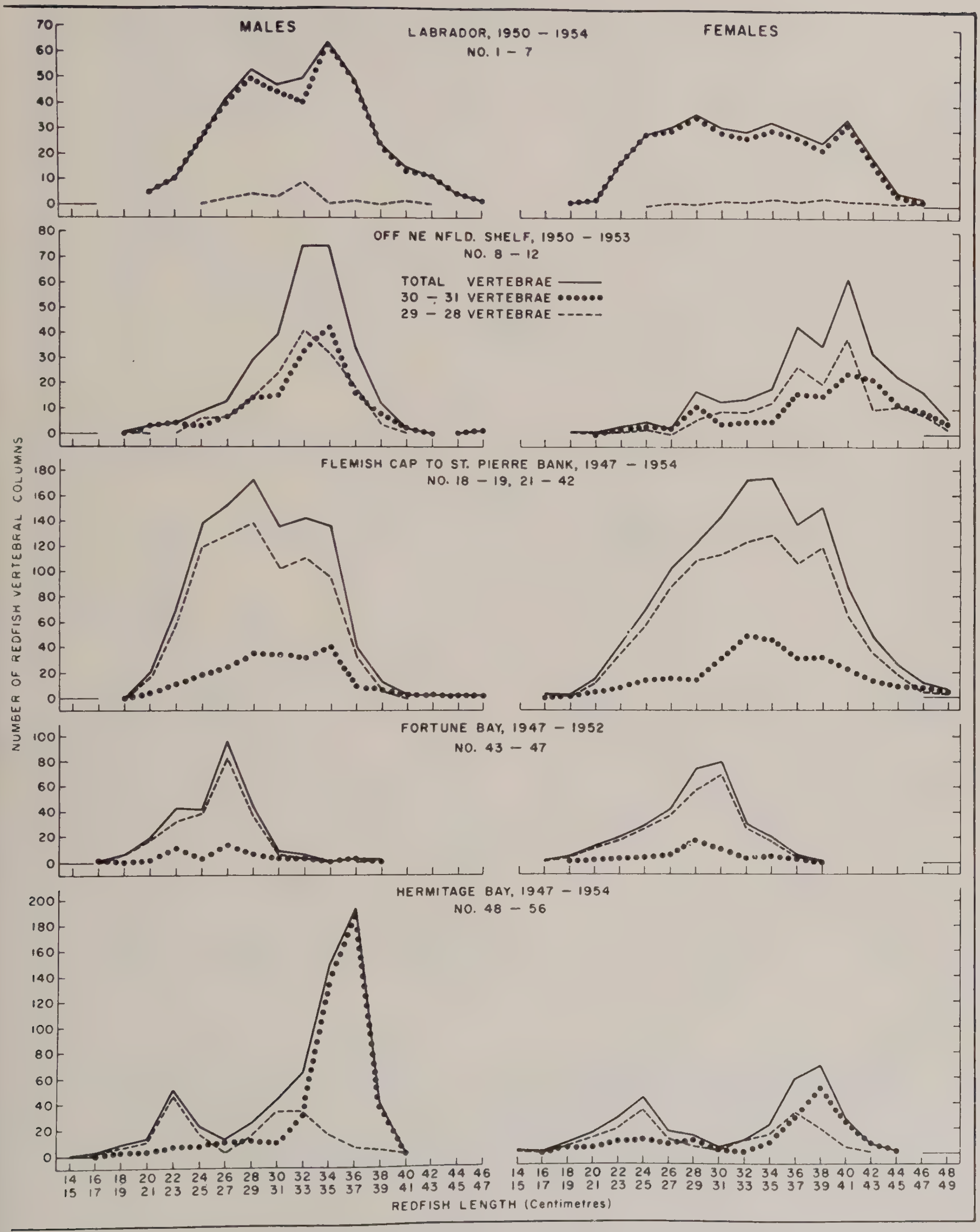

Figure 13. Relation of vertebral number and redfish length in area summaries from Labrador to Hermitage Bay.

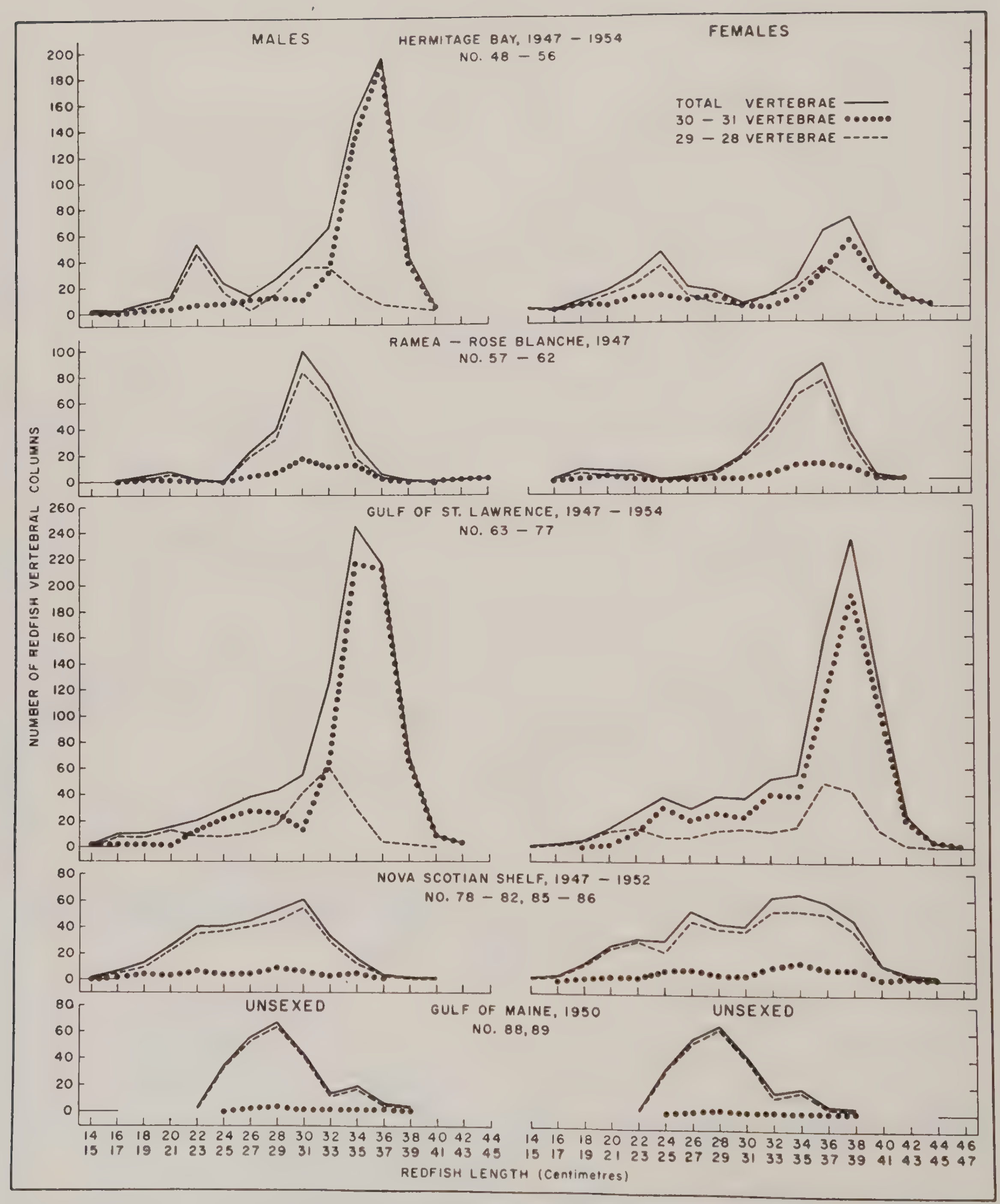

Figure 14. Relation of vertebral number and redfish length in area summaries from Hermitage Bay to Gulf of Maine.

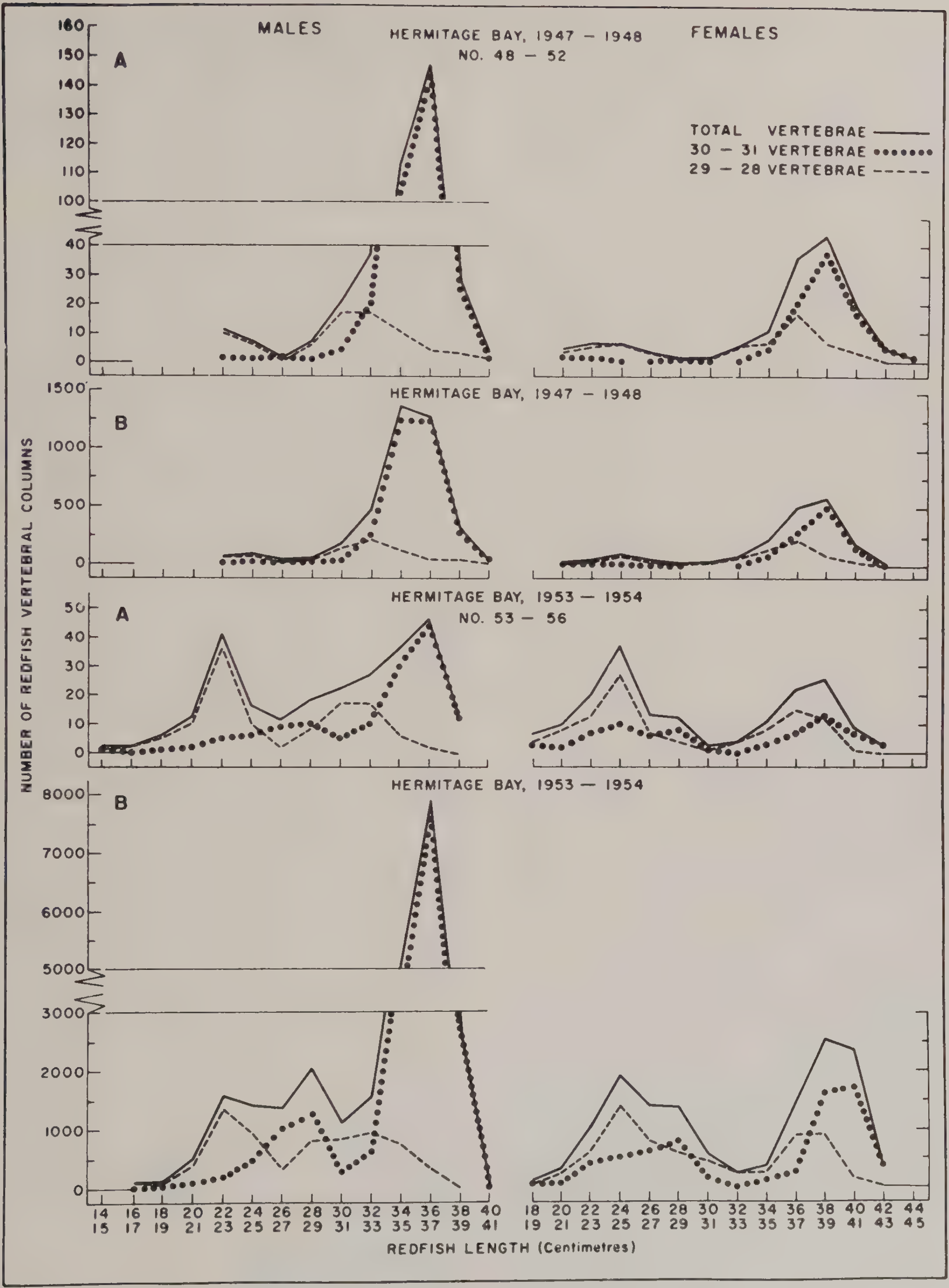

Figure 15. Relation of vertebral number and redfish length in vertebral samples from Hermitage Bay (A), compared with research vessel redfish length frequencies from the same area transformed by vertebral number/fish length keys to vertebral frequencies (B).

the actual length-frequencies have a general similarity to, but also some differences from, those of the redfish samples used for the vertebral counts. The details of this figure will be discussed later. By these calculations from a vertebral number/fish-length key, a more exact vertebral average for an area should also be obtained.

General discussion and conclusions for each area

Labrador

Most of the 7 Labrador samples with very high vertebral numbers at all lengths were from localities where few *marinus*-type redfish have been noted; their lengths were not those of the typically very large *marinus* fish; most of the depths were greater than those where *marinus*-type fish are abundant. Two samples were from 204 and 300 fathoms (373 and 549 m), at which depths *marinus*-type fish are usually very scarce, and yet in each case the sample had 98–99 % with 30–31 vertebrae. It may thus be said with some assurance that the *mentella*-type redfish in Labrador, south to Lat. 54°N, have a high vertebral number and that very few redfish at any length have fewer than 30–31 vertebrae.

Northeast Newfoundland Shelf and east coast bays

Between the high vertebral numbers in the Labrador area and the low ones on the north-eastern Grand Bank (samples Nos. 18–24) are found intermediate numbers (samples Nos. 8–12) significantly different from those of Labrador north of Lat. 54°N and usually from those of the north-eastern Grand Bank. In this general area, also, there are four high vertebral averages, three of which resemble the Labrador averages more closely than those of the areas in which they are located. In one of these areas, Badger Bay (sample No. 13, vert. av. 30·07, 100 % 30–31 vertebrae), there is a very low temperature (0·1°C) in redfish depths at 155–160 fathoms (284–293 m). The high vertebral averages for samples Nos. 16 and 17, Trinity Bay (29·96 and 29·74) are also associated with low temperatures at redfish depths (0·8 and 0·6°C at a depth of about 180 fathoms or 330 m). In the deep waters of these bays the population is of the *mentella* type. These bays and fjords on the east and particularly the north-east coast of Newfoundland are filled to a greater depth with water from the colder, inshore part of the Labrador Current than are the seaward slopes of the continental shelf.

The high vertebral average of sample No. 14, north-east of Cape Bonavista (30·04, 100 % 30–31 vertebrae, 175 fathoms, 320 m) came from a sample of mainly small fish (Figure 8), in which the few large females present were immature at a larger size than is usual for *mentella*-type redfish from this area and depth. There are very likely at least some *marinus*-type fish present, but it is felt that there is insufficient information on the relative numbers of *marinus*- and *mentella*-type redfish to explain the vertebral numbers in this sample with any degree of confidence.

There are probably a few *marinus*-type redfish in some of the other vertebral samples, Nos. 8–12, and 15, from the Northeast Newfoundland Shelf, but the evidence, from size at sexual maturity, is that these samples are mainly *mentella*.

Flemish Cap

Flemish Cap sample No. 20 (vert. av. 30·1, 100 % 30–31 vertebrae, 109–116 fathoms, 199–212 m, Figure 9) comes from an area and depth where investigations have shown that *marinus*-type redfish predominate. The predominantly large sizes and the large size at sexual maturity make it reasonably certain that this sample is entirely or almost entirely of the *marinus* type, whereas samples Nos. 19 and 21 (vert. av. 29·3, 71 and 72·% 29–28 vertebrae, 158–163 fathoms, 289–298 m, Figure 8) also from Flemish Cap are established, by their considerably smaller size at sexual maturity and their lack of very large fish, to be almost entirely *mentella*. The very largest sized redfish in these two samples, however, are larger than have been found in recent checks of the sizes of *mentella*-type redfish in the area, and the complete change-over to a predominance of the 30–31 vertebrae type among these large fish is certainly due to the presence of a few *marinus*-type redfish in the samples.

Eastern Grand Bank

Recent research vessel findings make it certain that the low vertebral numbers on the eastern slope of the Grand Bank (Nos. 18, 22–29, vert. av. 29·1–29·3, 72–94 % 29–28 vertebrae) are due almost entirely to *mentella*-type redfish. This evidence includes the finding of only very small numbers of *marinus*-type redfish on the eastern slopes of the Grand Bank and the presence at all depths of the much more numerous *mentella*-type redfish; the normally small (as for *mentella*) sizes at which sexual maturity occurs in the fish of these vertebral samples; the lack of numbers of very large fish (Figure 9) and the depths, all over 160 fathoms (293 m) and almost all over 170 fathoms (311 m). It is concluded that although at the very largest sizes (NE, SE and S Grand Bank, Figure 9) there may be a very few *marinus*-type redfish with the predominantly 30–31 vertebral count of that type, there are not enough of them to affect the vertebral averages significantly.

South-western Grand Bank

Marinus-type redfish are extremely scarce at any depth on the south-western part of the Grand Bank, although redfish are normally found there at the shallowest depths of any in the Newfoundland area, 50–80 fathoms (91–146 m). There is no evidence, either from sexual maturity or size, that there were any *marinus*-type redfish in the whole group of samples from the south-western slope of the bank. Certainly there are not enough *marinus*-type fish to affect the averages significantly, and they can therefore be considered to be of *mentella*-type redfish. Six samples in the central part of the south-western Grand Bank area (Nos. 30, 32–37) have vertebral averages between 29·04 and 29·21 with between 84 and 94 % of the vertebral numbers 29–28. These samples all come from depths of 45–150 fathoms (82–274 m) but this fact, together with the small size at sexual maturity, the generally small fish sizes and the knowledge that *marinus*-type redfish are absent from the area, indicates that these are *mentella*-type redfish. One sample, No. 31, is from the same area but from deep water, 230–360 fathoms (421–658 m); it possesses a much higher vertebral average of 30·0, with 88 % of the vertebral numbers 30–31. Similarly, the small size of sexual maturity; the absence of large *marinus*-type fish; the general knowledge of the area and the considerable depth which, over the whole area and especially west of the tail of the Grand Bank, is inhabited almost entirely by *mentella,* indicate this sample to be of the *mentella* type. They are, however, larger than *mentella*-type redfish from shallower samples from the same area and have the high vertebral numbers characteristic of the larger *mentella* from Hermitage Bay and the Gulf of St. Lawrence (Figures 10–15). This high vertebral count is thought to be due to their development during a period of water temperatures lower than those in which the shallower, younger and smaller redfish developed in recent years.

The most northerly of the samples from the south-western slope of the Grand Bank (No. 38–39), although from 52 fathoms (95 m), possess higher vertebral averages (29·46 and 29·45) and higher percentages (46 and 45 %) of fish with 30–31 vertebrae than the other samples mentioned above from the shallower water. These also give every indication, from the small size at sexual maturity and the absence of very large fish, that they consist mainly of *mentella*-type fish. They come from an area where much cold water from the cold inshore branch of the Labrador Current flows through the Haddock Channel and over Whale Bank. Hence, although the samples are from near the area south of Green Bank where *marinus*-type fish are common in about 90–120 fathoms (165–220 m), they are nevertheless considered to be most probably *mentella*, with the higher vertebral number usually found in colder water than is present farther south on the Grand Bank.

St. Pierre Bank and Halibut Channel

A sample with a still higher vertebral average (No. 40, vert. av. 29·7; 64 % 30–31 vertebrae) was taken in 70–90 fathoms (128–165 m) at the southern end of the Halibut Channel, east of St. Pierre Bank. This is a locality and depth in which many specimens of *marinus*-type redfish have since been collected. Also, the large sizes of many of the immature females and the numbers of fish of the larger sizes make it reasonably certain that this sample contained a large proportion of *marinus*-type fish, with the high vertebral numbers characteristic of this form.

The two samples (Nos. 41 and 42) from the western slope of St. Pierre Bank, with low vertebral averages of 29·2 and 82 and 85 % vertebral numbers 29–28, show no evidence either by sexual maturities or by sizes that *marinus*-type fish are present. Sample 41 from 148 fathoms (271 m) was from a depth where *marinus*-type redfish are exceedingly rare, west of the tail of the Grand Bank. In this whole area the usually few (but locally more numerous) *marinus*-type fish are found mainly between 90 and 120 fathoms (165–220 m). Sample 42 is from a depth (95–112 fathoms, 174–205 m), in which some *marinus*-type fish could be present in this area, but the available evidence indicates that no significant numbers of them were, in fact, present.

South coast of Newfoundland, Gulf of St. Lawrence, Nova Scotian Shelf, and Gulf of Maine

In the remaining Canadian area, the south coast of Newfoundland, the Gulf of St. Lawrence, and the Nova Scotian Shelf, there is no evidence, either from size at sexual maturity or from fish size, of *marinus*-type fish in these samples. They can all be considered as *mentella* type, with the possibility on the south coast of Newfoundland, near the southern entrance to the Gulf of St. Lawrence and on the northern Nova Scotian Shelf, that occasional individuals of the *marinus* type may be present, but not in sufficient numbers to affect the vertebral averages significantly.

South coast of Newfoundland

In the redfish area on the western part of the south coast of Newfoundland all the vertebral averages, except those from Hermitage Bay, are low. In Hermitage Bay (Nos. 48–56), where there is little variation in depth, vertebral averages are significantly different in many samples, ranging from 29·4 to 30·1, and with 38 to 98 % of the fish possessing 30–31 vertebrae. In these samples (Figures 10, 15 and Table 1) the vertebral numbers are predominantly 29 and 30–31 in the smaller and larger fish respectively — a distribution of vertebral number with size which has been relatively constant during the whole period of the investigation — and the vertebral average of any one sample therefore depends on the relative numbers of large and small fish in the sample. It is known from recent investigations over several years at the same stations in Hermitage Bay, that the numbers of large and small fish can vary with time of day and with time of year. At certain times, especially in late winter and early spring, preceding the spawning season, large mature females are very scarce, while the males of all sizes and the smaller females are usually present. Furthermore, in the earlier period (1947–48) the research vessel "Investigator II" was using a cod-end without a liner of shrimp netting, and thus there were fewer small fish in the catch and consequently higher vertebral numbers on the average than during the period 1953–54.

In Fortune Bay, east of Hermitage Bay (samples Nos. 43–47) and in the Ramea/Rose Blanche area west of Hermitage Bay (samples Nos. 57–62 (Fig. 14)) vertebral averages are low and significantly different from those of Hermitage Bay. These samples however, mainly consist of the smaller sizes at which similarly low vertebral numbers are predominant in Hermitage Bay (Figure 13). The predominantly low vertebral numbers can again be attributed to the predominance of small fish of a younger year- or period-class and the lack of large, older fish. Greater numbers of the larger and older fish, with a higher vertebral number, would doubtless have been obtained in these areas if the samples had been collected from greater depths.

Gulf of St. Lawrence

In the Gulf of St. Lawrence (Figures 11, 12, 14) in general the vertebral averages are high and the larger fish have a high vertebral number, as in Hermitage Bay; also, although not as extreme and general, the smaller sizes have, on average, a greater proportion of fish with low vertebral numbers, and thus the vertebral number depends somewhat on the sizes of fish in the sample and consequently on depth, season, time of day, etc.

Nova Scotian Shelf and Gulf of Maine

On the Nova Scotian Shelf (Nos. 78–86), low vertebral numbers predominate at both smaller and larger sizes (Figures 12, 14), and in the Gulf of Maine also (Figure 14) the redfish are almost entirely (95–97 %) of the lower numbers (29–28) at all sizes. Both of these areas have vertebral averages very significantly different from those of the Gulf of St. Lawrence. The large, older fish with higher vertebral numbers, if they were ever present, would be largely fished out in the Gulf of Maine, whereas most of the Gulf of St. Lawrence and Hermitage Bay samples came from a period either before commercial fishing began or while the redfish population was a relatively virgin one.

A comparison of the vertebral numbers at the large sizes in the overlapping parts of the curves in Figure 12 indicates that there are real differences between the averages of the Gulf of St. Lawrence part of the southern border of the Laurentian Channel (Nos. 74–77) and those of the neighbouring Nova Scotian Shelf (Nos. 78–82 and 85–86). Certainly the averages themselves are distinct. However, samples Nos. 75 to 77 were from 163–173 fathoms (298–316 m), whereas Nos. 78–82 were from 110–120 fathoms (201–220 m), except for sample No. 79 which was from 130–148 fathoms (238–271 m). Thus, it cannot be certain here that the actual change to much lower vertebral averages is as abrupt as it appears to be, because there may have been larger fish of an older generation and with higher vertebral numbers in the deeper water.

Part 2

Relationship of Redfish Vertebral Numbers to Environmental Conditions

Introduction

Because there is apparently only a small number of *marinus*-type redfish included, comment will be confined to *mentella*-type redfish. On hatching from the eggs redfish larvae remain in the ovary and oviducts of the parent until they have reached a stage, about 7 to 9 mm long, when they are perfect little larvae with eyes and eye-pigment well developed, the yolk sac completely absorbed into the normal body shape and are ready to feed.

Temperature and vertebral number

Gabriel (1944) found vertebral number to decrease continually with increasing temperatures between 13·5 and 24·5°C, during the development of *Fundulus heteroclitus* (L.). Dannevig's (1950) temperatures of development for plaice eggs ranged only between means of 4·9 and 5·4°C and yet his experiments indicated a decrease of 0·4 vertebra with only ½°C increase in temperature. It has been shown by the work of a number of authors (Schmidt, 1921; Tåning, 1944, 1952; Lindsey, 1954; Molander and Molander-Swedmark, 1957; Seymour, 1959) that lower temperatures during egg stages and early larval development of fishes increase vertebral numbers, whereas they are decreased at intermediate temperatures and increased again at still higher temperatures. There seems to be little evidence of such increase in vertebral numbers with high temperature in nature. It is possible that in the experimental environment there are often many factors which retard development and increase vertebral count, and that these will be especially present at high temperatures.

Temperature and stage of determination of vertebral number

Gabriel (1944) showed that vertebral number was not yet determined at the point of development when the first four or five somites had appeared, and that it was still affected by changes in temperature. He was of the opinion that vertebral number was determined before hatching and that the last possible stage for temperature control of vertebral number was at the time during late egg development when the intervertebral regions differentiate.

Tåning (1944,1952) in experiments on the sea trout, *Salmo trutta trutta* L. found that for a very short period in embryo development in the egg — from about 145 day degrees (D°) to 165 D° — the number of vertebrae could be readily changed by a change in temperature. This period is just before the development of eye-pigment in the embryo. After about 165–170D° the number of vertebrae was generally no longer influenced by small temperature changes. Tåning concluded that the number of vertebrae in the common fishes, such as cod, plaice, herring, etc. was certainly determined before the egg hatched, but that this still needed verification.

In the work of Dannevig (1950), although temperatures were not kept constant and all the results were not consistent, there was some indication that vertebral number in the plaice, *Pleuronectes platessa* L., was determined during development in the egg and not later in the larvae.

Seymour (1959), from the results of a chance exposure of the eggs of the chinook salmon, *Oncorhynchus tshawytscha* (Walbaum) to water of low oxygen content during early development, concluded that the plastic period for the determination of vertebral number begins before the mid-point of the egg stage.

The work of Lindsey (1954), however, for the paradise fish, *Macropodus opercularis* (L.), which differ from *Salmo trutta trutta* in that development to the hatching stage is very rapid, about 24 hours at 28°C, indicated that the caudal and consequently the total vertebral numbers in the larvae were subject to change by temperature as late as 13 days after fertilization (11–12 days after hatching).

Molander and Molander-Swedmark (1957), also produce evidence, from several experiments on plaice, that changes in temperature after hatching can change vertebral number. They concluded that in these experiments the determination of the number of vertebrae occurred later than 184D° (2 weeks after hatching) but earlier than 750D°. Thus, although Tåning's critical pre-eye-pigment stage for vertebral determination is probably more than a month before extrusion of the redfish larvae, these experiments on plaice, and on the paradise fish, leave the question still in doubt whether redfish vertebral number is in fact completely or mainly determined before extrusion. It is thus possible that vertebral number is influenced by hydrographic conditions either in deep water during larval development in the ovary, or in the more superficial water layers after the larvae are extruded. At the time of hatching the trout is a much larger and sturdier larva than the redfish and there may well be differences in the stage of development of these two forms, during which the greatest effect of temperature or temperature change on vertebral number occurs. Also, the location of most of the *mentella* females is not known for several months before the extrusion of the larvae (Templeman, 1959). They may be pelagic at this time and either shallower or deeper than their usual abode. This period, when the pregnant females are not numerous on their usual grounds, includes for many redfish Tåning's critical pre-eye-pigment stage for vertebral determination.

Salinity and vertebral number

Schmidt (1917, 1930) could see no proof in populations of *Zoarces viviparus* L. from the north European region, that the salinity was an effective agent in controlling vertebral number. He concluded that the same average number of vertebrae may be found in the North Sea as in the eastern Baltic, where the salinity of the water was only $^1/_9$ of the North Sea value. In other areas populations of *Zoarces* living in water of about the same salinity could have vertebral averages differing by as much as 12. *Zoarces viviparus,* however, produces large embryos 4 to 5 cm in length, with the vertebral number and even the fin ray number already determined long before birth (Schmidt, 1917). Because, presumably, the internal salt concentration of the female parent is not greatly different in waters of different salinity it is not to be expected that the vertebral numbers of the developing embryo of *Zoarces viviparus* would be affected greatly by the variations in the salinity of the parent fish's external environment.

In the cod, on which information is available for the Baltic and for the whole North Atlantic (Schmidt, 1930), it is apparent that water temperatures rather than the low salinities influence the vertebral number determination in the eastern Baltic.

Heuts (1949) showed that the number of fin rays in the developing stickleback, *Gasterosteus aculeatus* L., depend on both temperature and salinity.

Compared with the range of temperature variation there does not appear to be any considerable variation in salinity in redfish depths and ranges in the Northwest Atlantic. As for *Zoarces viviparus,* it is unlikely that variations in salinity of the external environment could have any great effect on the vertebral number of developing redfish eggs or free larvae within the female parent.

Similarly, such small salinity variations as occur within the surface layers do not appear to be related to variations in vertebral numbers. The lowest surface salinities in the redfish areas are in the Gulf of St. Lawrence, but the vertebral numbers in this area are intermediate between the higher Labrador and lower Gulf of Maine numbers. In both these latter areas salinities are higher than in the Gulf of St. Lawrence (Hachey *et al.*, 1954).

The effect of changes in oxygen tension and carbon dioxide tension

Tåning (1952), showed that decreasing the pressure of either oxygen or carbon dioxide during development of the sea trout produced an increase in the number of vertebrae.

In the North-west Atlantic (Sverdrup, Johnson and Fleming, 1942) there is a reduction in oxygen content and an increase in carbon dioxide content from north to south. From the results of Tåning's experiments these should have opposite effects on the vertebral number. Apart from the general trend in distribution of oxygen and carbon dioxide there are considerable diurnal differences in the oxygen and the carbon dioxide content of the surface layers, especially during the season of phytoplankton bloom; there should also be considerable differences in the depth relationships of the larvae to the surface during day and night. The effects of these factors on redfish vertebral numbers cannot be discussed in detail, from lack of adequate data.

The effect of varying light intensity

The work of Dannevig (1932) indicated the possibility that higher light intensity reduced vertebral number during the early larval period of the cod, *Gadus callarias* L. The lack of information, however, on the source of the larvae and the conditions under which the eggs developed, the lack of suitable controls for comparison, and the fact that higher temperature may also have contributed, renders the observation of doubtful significance. McHugh (1954), in experiments on the grunion, *Leuresthes tenuis* (Ayres), found evidence that increasing intensity of light during embryonic development was associated with lower vertebral numbers. Lindsey (1958) for the kokanee, *Oncorhynchus nerka* (Walbaum), found that a 16-hour exposure to artificial light produced a significantly lower number of caudal vertebrae than an 8-hour exposure of the same intensity.

It is apparent that differences in intensity or duration of light cannot affect the redfish eggs or larvae within the ovary of the parent, but only the larvae after extrusion. It is likely that, since redfish rise off the bottom at night, the duration and intensity of light can affect the amount of time the mature female spends pelagically in water which is (over most of the North-west Atlantic) colder than the deeper water near the bottom.

Flemish Cap and the north-eastern part of the Grand Bank are in the same latitude as the south-eastern part of the Gulf of St. Lawrence, and yet vertebral numbers of *mentella*-type redfish are low in the first two areas and generally high in the Gulf. Vertebral numbers on the north-eastern Grand Bank are as low as those of south-eastern and south-western Grand Bank, a difference of 4 to 5 degrees of latitude. The low vertebral numbers of north-eastern Grand Bank and Flemish Cap are approximately in the same latitude as the high vertebral numbers of Trinity Bay. Hence it is unlikely that the vertebral differences between redfish in the North-west Atlantic can be readily explained by light differences, although allowances must be made for foggy Grand Bank areas; for differences, in light penetration between silty water such as that of the Gulf of St. Lawrence and the clearer oceanic water, and for the unknown ability of the larvae to adjust themselves to approximately the same light intensities in different areas.

Differing vertebral numbers in the same area

Many authors including Lea (1919) and Runnstrøm (1933) have shown that in Atlantic herring, *Clupea harengus* L., the mean vertebral numbers of different year-classes from the same locality may differ significantly.

Rounsefell and Dahlgren (1932) found significant differences between the vertebral averages of different year-classes of Pacific herring, *Clupea pallasii* Valenciennes, from Prince William Sound, Alaska; there was a negative correlation between the vertebral averages and mean air temperatures during the spawning months.

Tester (1937) showed, for a number of British Columbia localities, many significant differences between vertebral averages of Pacific herring of different year-classes in the same area. He also showed a negative correlation of vertebral number with air temperature for Jap Inlet.

Tester (1938) found a negative correlation between mean vertebral number of Pacific herring and water temperatures during the spawning period in Berkley Sound, British Columbia.

McHugh (1942) showed that samples of young herring in British Columbia may differ widely in vertebral count in the same locality in different years. Also fish from successive spring spawnings in the same area with increasing water temperatures, showed declining vertebral averages.

Vertebral number and fish length in the same year-class in the same area

Thompson (1917), for year-groups 3 to 5 of the Pacific herring, indicated the possibility that the larger individuals of a year-class may have a higher number of vertebrae than the smaller individuals.

Similarly Hubbs (1925), for the 0-group of the Pacific herring, found the larger fish to have a higher vertebral number, and attributed both characteristics to earlier hatching of the larger fry. These larger fry were products of earlier spawning. They developed in lower temperatures and thus had higher vertebral numbers and grew to a larger size than the fry from eggs spawned later.

The work of Dannevig (1933) for 0-group fish of the coalfish, *Gadus virens* L., collected from four Norwegian areas, gave strong evidence that the larger fish of a year-class had a higher vertebral number than the smaller fish.

Mottley (1937) showed that in 0-group fish of the same brood of rainbow trout, *Salmo gairdnerii* Richardson, all reared under the same experimental conditions, there was a significant correlation between length of fish and the number of vertebrae, larger fish having higher vertebral numbers.

Tester (1937) showed that there was a slight tendency for the larger fish of 3- and 4-year-old Pacific herring to have higher vertebral counts. In comparisons of herring with 51–53 vertebrae an increase of 1 vertebra, however, was associated with a gain in length of only between 0·1 and 0·2 cm in fish about 19 cm long.

McHugh (1942) also showed that in the Pacific herring larger fish of the same year-class had a higher vertebral count than the smaller fish.

The fish described above as showing an increasing vertebral average with increasing size, under natural conditions spawn in the early part of the year, when temperatures are rising; they are therefore not comparable to the redfish, because the redfish live in deep water which changes little in temperature throughout the year. The comparison would hold better, however, if the final determination of vertebral number in the redfish were made in the upper water layers after extrusion.

On the other hand, Ford (1930) found that, for young herring in their first year at Plymouth, the average vertebral number decreased with increase in length. This appears to be an exception which proves the rule, because these Plymouth herring (Ford, 1928) spawn from late September to March over a period with gradually declining temperatures. Thus the young herring from early spawnings, which develop at higher temperatures, grow larger and have a lower number of vertebrae than those from eggs spawned later which develop at lower temperatures.

Causes and implications of differences in redfish vertebral numbers in the same area

Hermitage Bay

In most localities of the North-west Atlantic there is some variation in redfish vertebral number with size and presumably age, so that the vertebral average depends to some degree on the sizes collected and thus, in *mentella*-type redfish at least, on the depths fished, and, since mature females are not equally available in all months, on the season of the year. There are some areas where the differences in vertebral number at various sizes are more extreme. Among them is Hermitage Bay, for which there are abundant data, showing double-peaked length-frequency curves for both males and females (Figure 10). The peak at the larger sizes, possessing predominantly 30–31 vertebrae, is distinct by many years (about twenty; see later discussion) from that of the smaller sizes, where vertebral numbers 29–28 are predominant. These smaller sizes are about ten years of age. The larger fish with predominantly 30–31 vertebrae have apparently attained their maximum size. There was no change in size for this group between 1947–48 and 1953–54 in vertebral samples (Figure 10) and little change in the length-frequencies (Figure 15). These fish may, therefore, have been close to their maximum size for many years before 1947–48.

In the North-west Atlantic redfish live in the warmer layer below the cold upper or intermediate portion (depending on season) of the Labrador Current (Templeman, 1959). It is well known that during colder years or periods the superficial layer of cold water is colder, greater in volume and extends more deeply than in warmer years and periods. There are occasional unusually warm years during cold periods and vice versa. The area of Hermitage Bay receives its cold water from local cooling and by the overflow from the cold inshore branch of the Labrador Current passing through the channel between St. Pierre Bank and the Burin Peninsula. Since this channel is shallow, with depths of about 50–60 fathoms (90–110 m), the deeper water of the Hermitage Bay area is protected to a large degree from the colder water of the Labrador Current. In cold periods and cold years, however, the colder overhead ceiling will extend to the upper part of what in warmer years would be 3 to 5°C water inhabited by redfish. Both surface and bottom water temperatures in this bay, also, are reduced somewhat in the colder years.

Redfish migrate upward at night. Also, most female redfish disappear from the fishery for several months before spawning, and presumably move either pelagically or deeper than the usual fishing depths. It cannot be ascertained whether at this time they live at a higher or a lower level than during their known period of bottom-related existence (Templeman, 1959).

The larvae of the *mentella*-type redfish of the approximately 120–160 fathom (220–290 m) Hermitage Bay area are mainly extruded in May, June and early July. At the bottom of the bay, in shallower colder water at about 100 fathoms (185 m) where a small redfish population exists, larval extrusion is later, possibly by as much as a month. The larvae are fully developed, with the yolk sac absorbed into the normal body shape, before extrusion. Thus, if the redfish is similar to the sea trout in this respect (Tåning, 1944, 1952), vertebral number would have been established for some time before extrusion. The redfish distribution over the whole area tends to be deeper if the overhead layer of cold water is colder and thicker. Thus, in years when the upper part of the redfish habitat is either colder or warmer than usual, the final depth and temperature arrangements of the redfish would probably be a compromise between their normal depth habits and their reaction to the lower or higher temperatures. It follows, furthermore, that in colder years and periods the female redfish, with their developing larvae, live in colder water than during warmer years and periods. From the later discussion, however, it will be apparent that the vertebral number in redfish of the North-west Atlantic is very likely determined in the larval stage after extrusion, by the temperature of the surface water layer in May and early summer.

Climatic changes in air and sea of the western North Atlantic area in recent decades have been discussed by Jensen (1939), Smed (1947, 1949), Tåning (1953), Templeman and Fleming (1953), Riehl (1956), Lauzier (1954, 1958), and by Taylor, Bigelow and Graham (1957). Although there are some warm years during cold periods and some cold years during warm periods, sea temperatures have increased considerably, at least in the surface layers, since the early 1920's, reaching higher levels particularly since 1940.

Otolith readings of these Hermitage Bay *mentella*-type redfish by E. J. Sandeman of the St. John's Station have indicated that in 1947–48 larger fish, with predominantly 30–31 vertebrae, were mainly between 25–40 years of age, whereas the smaller fish in the vicinity of 25 cm, with predominantly 29–28 vertebrae, were mostly 8–12 years old in 1953–54. Thus, the year-classes producing most of the group of larger redfish with high vertebral number were those produced during the earlier cold period before 1920, whilst the smaller fish, with chiefly lower vertebral numbers, were developed in the later warmer period.

Apart from the fact that the older size group developed as larvae during the earlier colder period and the smaller size group during the more recent warmer period, there is a gap of about twenty years between the peaks of these two groups, indicating that abundant larval survival in the area occurred only in occasional years. Thus, in warmer years during cold periods or in colder years during warm periods, if they were years of considerable larval survival, redfish with lower or higher vertebral numbers could be produced in sufficient numbers to affect significantly vertebral averages in an area.

There are, of course, definite indications in the Hermitage Bay data (Figures 10, 14) that there is another moderately strong year-class or period-class with predominantly 29–28 vertebral number, somewhat hidden in the skewed left side of the peak of larger fish of predominantly 30–31 vertebral number and centering on 30–33 cm in the males and on 36–37 in the females. There are also indications in the 1953–54 data (Figure 10) especially for the males, of another year-class or period-class, with predominantly 30–31 vertebrae, centering on 26–29 cm. In the actual length-frequency for Hermitage Bay 1953–54 (Figure 15 B) this latter group is very strong and readily distinguished, with a distinct peak at 28–29 cm in the curve of the males but less distinct in that of the females.

Thus, in Hermitage Bay, during the period considered in this paper, the vertebral average depends on the relative numbers of large and small redfish in the sample, and a sample of mainly small fish would usually have a vertebral average significantly different from one in which large fish predominate.

Gulf of St. Lawrence

In the Gulf of St. Lawrence area (Figure 14) it is probable that the same four groups occur, two predominantly of high vertebral number and two of low, but, possibly because of the combination of a very wide area and a span of years from 1947 to 1954, the two largest size groups with distinct numbers of vertebrae are not so different in length.

The four groups 1, 2, 3 and 4 mentioned above, 1 and 3 of low vertebral number and 2 and 4 of high vertebral number, are not found together in all samples from different parts of the Gulf (Figures 11, 12). Sometimes this is very likely due to the smallness of the sample and to collecting redfish from only a small part of its depth range, so that all sizes of fish are not obtained. In other areas all year- or period-groups may not be present. More data than are available at present are needed from local areas of the Gulf in order to provide the correct explanation. St. George's Bay (Figure 12) possesses all four groups. Group 4, consisting of large fish with high vertebral number, is common to most areas of the Gulf. Group 3, with low vertebral number is usually, but not always, of lower length than Group 4.

Use of frequencies of differing vertebral numbers as aids for dissecting length-frequencies and for checking age estimation

In many of the samples of Figures 8–15, such as those from Labrador, Nos. 1–7; Badger Bay, No. 13; north-east of Cape Bonavista, No. 14; Flemish Cap, No. 20; the Nova Scotian Shelf and the Gulf of Maine, no difficulties of interpretation arise, since the vertebral numbers at all sizes are very predominantly of one type.

In others, as for example Flemish Cap Nos. 19 and 21, north-east Grand Bank, south-east and south Grand Bank, Fortune Bay, Ramea and Rose Blanche, considering both male and female, the main peaks of the frequencies for 29–28 vertebrae and for 30–31 vertebrae, although of different heights, generally fall on the same centimetre sizes and consequently these fish can be supposed to belong to the same year-classes or period-classes.

There is a third group of frequencies, of which Hermitage Bay is the best example, because of the small size of the area, the numbers of redfish examined for vertebral number and the large number of redfish measured. In this group the adjacent frequencies of low vertebral number and of high vertebral number against fish length are different enough to make it more difficult to believe that they belong to the same year-class or period-class. In Figure 15, for example, in which the vertebral-frequency data have been applied to the much larger amount of length-frequency data from the Hermitage Bay area, the group of large redfish with a high vertebral number of 30–31 is readily recognizable for both sexes, both in the 1947–48 and in the 1953–54 periods. In both periods the high-vertebral-number male group is almost entirely contained between 30·5 and 40·5 cm, with the curve approximately balanced at 35·5 cm in 1947–48 and with a peak at 36·5 cm in 1953–54. In the females the high vertebral group in the larger Hermitage Bay redfish has its peak frequency at 38·5 cm for the 1947–48 period and at 39·5 cm for 1953–54. Obviously the redfish of the largest size group have about reached their maximum length and growth has ceased or is very slow.

Another group with high vertebral numbers extends in the 1953–54 period from about 18·5 to 30·5 cm in the males and about 20·5 to 32·5 cm in the females, with peaks in both cases at 28·5. Obviously this is a year-class or period-class separate from the group of larger fish with similarly high vertebral numbers, and thus its growth can be followed separately until it merges with the larger fish. This group is not apparent in the 1947–48 data, either because too few small fish were examined, or because it has moved into the area or into the depths fished during the intervening period.

To the left of each group of high vertebral number (males and females) there is a relatively distinct group of redfish with the lower 29–28 vertebral number. Two possibilities exist: (a) that these low vertebral number frequencies, although receiving some low vertebral count recruitment from the same year-classes which produced the peak frequencies with high vertebral numbers, are in the main separate frequencies from year-classes different from those producing the higher vertebral numbers; (b) that the low-vertebral-number fish belong to the same year-classes which produced the fish with high vertebral numbers, but by reason of their fewer vertebrae or from being born later in the season have been handicapped in growth and have not reached the size attained by the fish with higher vertebral numbers. The accuracy of age estimation in redfish at the present time does not appear to be great enough to settle this question completely and in any case not enough age-reading has been done for the redfish of this area to render other types of argument superfluous. It is obvious, however, that there is a good opportunity to check age-reading for the largest group with high vertebral numbers, because ages should have increased by 7 years between 1947 and 1954.

In 1953–54 the smaller-sized low-vertebral-group centred on 22·5 cm in the male and 24·5 cm in the female, and the larger-sized one at about 31·5 cm for the males and 37·5 cm for the females. These size differences are due to the faster growth of the females, which again is presumably due to their becoming sexually mature in this area at about 30 cm, compared with usually less than 20 cm for the males.

In the males the larger-sized low-vertebral-group shows no growth progress whatever in the six years between 1947–48 and 1953–54. The centre of the length-frequency of females of this group has moved 1 cm, from 36·5 cm in the earlier to 37·5 cm in the latter period. Thus it may well be argued that this group also has approximately attained its maximum size. The smaller-sized low-vertebral-group, so evident in 1953–54, may be represented also in the scanty material for these sizes obtained in 1947–48, and again there is no evidence of growth of this group in the intervening period. However, the absence of small-meshed netting in the cod-end during the 1947–48 period means that this youngest group was not fully represented in the samples, especially at the smaller sizes. In the Hermitage Bay area small redfish are more numerous in water of about 20–30 fathoms (35–55 m), shallower than the deep water area of the bay from which most of the above specimens came. Still deeper water is present in the outer part of the bay and outside it. In general these *mentella*-type redfish are larger at greater depths. There is a possibility that the larger individuals of a year-class gradually migrate deeper at an earlier age than the smaller members of the same year-class. The presence of widely distinct size groups, however, at the same depth indicates that this factor will probably be responsible for only small differences in the length-frequencies, usually not greater than several centimetres, but the possibility must be kept in mind in growth studies of redfish.

Considering again the 1953–54 redfish from Hermitage Bay (Figure 15 B), in view of their very slow growth it seems unlikely that the low-vertebral-count length-frequencies, with modes at 22·5 and 24·5 cm respectively for males and females, are mainly from the same year-class which produced the high-vertebral-count length-frequencies with modes of 28·5 cm for males and females. Similarly the larger-sized low-vertebral-count frequency for males centred at about 31·5 cm is, in view of the very small yearly growth at these sizes, very distinct from the high-vertebral-count groups with modal size of 36·5 cm. The comparable groups of females, though still about 2 cm apart, have come closer together in the seven years from 1947–48 to 1953–54, since with the larger group almost at a stand-still, the faster growing females have more rapidly approached the maximum size. However, there is again good reason to believe that, for redfish near their maximum size, 2 cm represent many years of growth. As a counter argument, if they do not belong to the same year- or period-classes, it is a strange coincidence that the high-vertebral-number frequencies alternate so regularly with the low-vertebral-number frequencies.

In an area such as Hermitage Bay, where different year- or period-groups may have distinctly different vertebral numbers, the collection of adequate length-frequency and vertebral-count data, preferably from different depth levels, may enable age and growth to be determined independently of age-reading. Combined with age-reading it may serve as a check on its accuracy, and may even show how this can be improved. This will especially be the case when such a distinct age- or period-group can be followed throughout its lifespan.

Reference to Figures 10–12 indicates that, in addition to Hermitage Bay, the same technique may be applicable to many areas of the Gulf of St. Lawrence. There may also be a number of other areas where the technique could be used if adequate observations were taken over a sufficient number of years.

Part 3

Relationship of Redfish Vertebral Numbers to Temperature in the North-West Atlantic

Introduction

For marine fishes in nature and especially for known spawning stocks, it is often possible to attribute variations in vertebral averages, at least in large part, to temperature during egg and early larval development (Schmidt, 1930; Runnstrøm, 1933; Rounsefell and Dahlgren, 1932; Tester, 1937, 1938; McHugh, 1942). Because factors other than temperature, known from experimental evidence to affect vertebral numbers of certain fishes, are either unlikely to be very important in determining redfish vertebral numbers in the area, or cannot be discussed for lack of data on the distribution of these factors in the sea, only the evidence of a relationship between vertebral number and temperature will be considered in detail.

The discussion must begin with the fact that due to the differing results of the experiments of various workers (see previous discussion) on the stage of fish development in which vertebral number is determined, it cannot be certain whether the redfish vertebral numbers are entirely or mainly determined in deep water in the ovary of the female before extrusion or in the surface layers where the fry are most abundant after extrusion. These observations are restricted to the *mentella* type.

In Hermitage Bay extrusion of larvae by *mentella*-type redfish extends from April to September but almost all occurs between May and early July. In at least most of the remainder of the Newfoundland area the main time of extrusion appears to be approximately this same period of May to early July. The limited data of Bigelow and Schroeder (1953) indicate a similar time of extrusion for redfish in the Gulf of Maine, though possibly a few weeks later. The vertebral column of the 7 to 9 mm larva at the time of extrusion is not ossified and vertebral numbers cannot be determined.

Tåning's critical pre-eye-pigment period, at which the number of vertebrae in the sea trout were readily influenced by a change in temperature, is probably more than a month before extrusion of the redfish larvae. This would make the months of March–May most significant if vertebral number is mainly determined in the egg, April–June most important if it is determined in the hatched larvae within the female ovary, and May to June or to early July most important if vertebral number is mainly determined during early larval growth soon after extrusion. It is presumably possible for the vertebral number to be influenced by temperature at any one of these three stages.

There remains the additional complication that on the way to the higher layers the larvae may often pass through water colder than that to which they were exposed while within the parent redfish. This water may be much colder, often below 0°C, as is generally the case in the Gulf of St. Lawrence and often on the fringes of the Grand Bank, especially the eastern slope, and also on the western slope of St. Pierre Bank and the northern, north-eastern and coastal parts of the Nova Scotian Shelf. The larvae may also take so long in passing through this colder layer, that some increase of vertebral number (through low temperature shock) may possibly occur if it has not already been determined before extrusion. It is difficult to see, however, how this idea can help to explain differences in vertebral numbers.

Factors other than temperature

It is possible that the discussions above have already complicated the matter enough. However, larval drift and the amount of redfish migration must also come into the picture, and genetic influence may be important. The discussion of these matters must, in the main, be left to the future when evidence may be found on the subject of migrations of *mentella*-type redfish within the area, and further knowledge of genetic influence, of redfish larval drifts, or of the most critical egg or larval period for effect of temperature on vertebral number may be gained. Furthermore there is at present too little information available on such matters as oxygen and carbon dioxide contents of the sea in the redfish areas, and on other influences, which may affect the vertebral number. Knowledge is lacking concerning the vertical distribution and temperatures experienced by the larvae, either within the parent or in the sea. More detailed information on the spawning period is required for many parts of the area. When vertebral frequencies and fin ray numbers of *mentella* and *marinus* types are available over the whole vertical and horizontal range in the area, it may be possible to analyse differences more clearly. Finally, more knowledge is needed on the ages of redfish in these samples and on their biology and its relationship to the environment of the area.

Vertebral numbers in relation to deep-water temperatures at redfish levels

In Labrador redfish live mainly in water between about 2·5° to usually 3·5° to 3·9°C. They are found at similar or even slightly lower temperatures on the continental slope of the Northeast Newfoundland Shelf and on the north-eastern and eastern slopes of the Grand Bank. Their Flemish Cap temperatures are usually slightly below 4°C. In the central part of the south-western slope of the Grand Bank deep-water temperatures at redfish depths are highly variable, usually between 2° and 8°C, but are probably on the average mainly between 4° and 6°C for mature females.

In the Gulf of St. Lawrence, in the seaward extension of the Laurentian Channel between St. Pierre Bank and Banquereau, and on the south coast of Newfoundland, most redfish live at between 3° and 5·5°C. In the Gulf of Maine and in the area covered by the samples from the southern Nova Scotian Shelf, temperatures in March–April at redfish depths were usually found to be approximately 3° to 6°C. For a more detailed account of the depth distribution of redfish in relation to temperature, see Templeman (1959). The temperatures on which the remarks above are based are mainly from summer and autumn sections, but since the redfish water is mostly below the influence of winter cooling the remarks should hold for the late spring and early summer period also, when vertebral number determination should be occurring.

On the basis of vertebral number determination within the ovary of the female in deep water it is possible that the Labrador deep-water temperatures are that much lower than those of the south-western Grand Bank, the southern part of the Nova Scotian Shelf and the Gulf of Maine as to produce the existing vertebral differences, the averages being almost 1 vertebra higher in Labrador than in the other areas mentioned. Temperatures are similarly lower at redfish depths in Labrador compared with the Gulf of St. Lawrence, the Laurentian Channel and the western part of the south coast of Newfoundland. Whilst some of the younger redfish in these latter areas, however, have low vertebral numbers, most of the older and larger redfish have high ones similar to those of Labrador.

The Flemish Cap temperatures at the main redfish depths are only about 0·5° to 1°C higher than those of Labrador, and, allowing for the presence of some high vertebral count *marinus* types in the samples, the Flemish Cap averages of *mentella*-type redfish are almost 1 vertebra lower than the Labrador vertebral numbers. The production of this great vertebral difference in a fish with so few and so large vertebrae as the redfish, by so small a temperature difference, is difficult to imagine, but it may be more reasonable if the *mentella* redfish live in shallower depths during the critical egg determination stages. This would bring them into temperatures of 1° to 2°C or lower in Labrador, whereas at the shallower redfish depths on Flemish Cap temperatures are very similar to those of the deep water.

However, there is some indication in recent Russian data (Travin, 1959) that redfish go deeper during the winter months. This is true for other fishes of the area, the cod and haddock, and hence is very likely true of the redfish. Thus there is the probability that the large differences in vertebral number of Labrador and Flemish Cap *mentella*-type redfish occur with only small differences in temperature during the critical determination period in the egg or early larva within the female.

Still more difficult to explain on the basis of ovarian determination of vertebral number are the lower vertebral numbers (lower than for Labrador) over the Northeast Newfoundland Shelf, and the still lower vertebral numbers on the north-eastern and eastern slopes of the Grand Bank. Temperatures at redfish depths over the Northeast Newfoundland Shelf are generally between 1·2° and 2·5°C. These are lower than the normal 2·5° to 3·5° or 3·9°C at the continental slope east of Hamilton Inlet Bank. Eastward of the Northeast Newfoundland Shelf and on the north-eastern and eastern slopes of the Grand Bank, temperatures at redfish depths are little different from those east of Hamilton Inlet Bank in southern Labrador, and yet vertebral numbers are typically a half vertebra lower on the Northeast Newfoundland Shelf than off Labrador and almost a vertebra lower on the north-eastern and eastern slopes of the Grand Bank than off Labrador. In the Grand Bank area, although temperatures are several degrees higher on the central slope of the south-western Grand Bank than on the eastern and north-eastern slopes of the bank, vertebral numbers are approximately similar in this whole area.

Samples Nos. 13, 16 and 17 from the Newfoundland east coast bays have a high vertebral number, related to lower temperatures at appropriate depths in these bays than on the continental slope from Labrador to the eastern Grand Bank.

Temperatures are higher in the Gulf of St. Lawrence than on the northern and eastern slopes of the Grand Bank, but vertebral numbers are considerably lower in the latter area.

Neglecting the question of larval drift, and seeing very little possibility that the main differences in vertebral number can be accounted for on the basis of migration of redfish after descending into the bottom water layers, there remain the major differences in vertebral numbers in relation to only small differences in temperatures. In some cases there is agreement between lower deep-water temperatures and higher vertebral numbers, and in other cases there are major differences in vertebral numbers with little or no differences in temperature. In some areas higher vertebral numbers and also higher deep-water temperatures are found than in others. With the present knowledge, therefore, the argument is very imperfect for a relationship between the temperatures at redfish depths and the vertebral number. Consequently there is no very clear indication that vertebral number is completely or mainly determined in the egg or hatched larva within the ovary.

Relationship of vertebral numbers and temperatures in the upper water layers

The limited information available at present on larval distribution (Templeman, 1959) indicates that the redfish larvae are most plentiful in the upper 50 metres or even close to the surface. In rising to the surface layers there will often be a considerable temperature change and thus some shock, which Tåning (1944, 1952) found very effective in changing vertebral numbers in trout larvae.

The period when the larvae rise to the surface over the greater part of the area is most likely to be May to early July, but surface water temperature data (most readily available as indicative of the upper 50 metres) for the main redfish areas of the North-west Atlantic in the same month and year as these samples are for August 1950 (Hachey, Hermann and Bailey, 1954). In that month, in the areas from which vertebral samples have been taken, surface temperatures were approximately as follows: east of Hamilton Inlet Bank, 6° to 8°C, with still colder water (4° to 5°C) on the inshore border; north-eastern Grand Bank, 6° to 8°C; Flemish Cap, 8° to 9°C; eastern slope Grand Bank, 7° to 10°C; east coast Newfoundland bays, probably 12° to 13°C; Gulf of St. Lawrence and western part of south coast of Newfoundland, 13° to 15°C; Nova Scotian Shelf, mainly 14° to 16°C with some water of 10° to 15°C at the coastal, south-western, part of the Nova Scotian Shelf and in the northern part of the Gulf of Maine. In the southern part of Gulf of Maine temperatures (from Bigelow, 1927) were about 18° to 20°C on the average in August, and on the south-western Grand Bank, 16° to 18°C.

There is even less agreement between vertebral number and surface temperatures in August than there is with vertebral number and deep-water temperatures. The differences between the low-surface-temperature high-vertebral-number Labrador area and the high-surface-temperature low-vertebral-number south-western Grand Bank, Nova Scotian Shelf and Gulf of Maine areas are great and in the right direction. However, although the surface temperatures of the eastern Grand Bank and Flemish Cap are considerably lower than those of the Gulf of St. Lawrence and off the south-west coast of Newfoundland, there are lower vertebral numbers in the former than in the latter areas.

From other sources surface temperatures in May and June are available for comparison from a few widely separated parts of the area.

On the redfish grounds east of Hamilton Inlet Bank, during an "Investigator II" cruise in 1958, which was not an especially cold year, surface temperatures obtained on 8.–10. June ranged from 0·2° to –0·5°C, and for 8 stations averaged –0·1°C.

At the hydrographic station 2 miles off Cape Spear near St. John's, surface temperatures in May 1947–1957 averaged 1·1°C and during June 5·1°C. In some years surface temperatures in May were as low as –0·5°C. These may be taken as indicative of surface temperatures in Trinity Bay and Badger Bay, although those of Badger Bay may be lower.

In the Gulf of St. Lawrence (Lauzier, *et al.*, 1957) from observations for a number of years, surface temperatures over the deep channels were mainly 2° to 4°C in May (4° to 6°C in May 1948) 4° to 7°C in June, 12° to 17°C in July and approximately the same in August.

Over the Grand Bank redfish area in 1934 (Smith, *et al.*, 1937) surface temperatures ranged approximately from 3° to 4°C at the north-eastern corner on 17.–20. May, from 3° to 4°C on the mid-eastern slope, 22.–23. May, and from 3° to 6°C on the south-western slope, 19.–20. April. At 43 stations well distributed on the redfish grounds between 85 and 780 metres on the south-western slope of the Grand Bank from 1. to 13. May 1959, surface temperatures taken from the research vessel "A. T. Cameron" ranged from 2·3° to 4·8°C and averaged 3·4°C.

Over the deep channels of the Gulf of Maine (Bigelow, 1927), the surface temperatures for the first half of May 1915 were 4° to 6°C, whilst in mid-June, for a combination of years, they were 9° to 13°C. By mid-August surface temperatures were 16° to 20°C over the areas of the Gulf containing most of the redfish (from available information for a number of years).

When the surface temperatures in May and June are considered, particularly those of early June in Labrador as compared with those for May in other areas, it is evident that there is an extremely good association of high vertebral number and low surface temperature in Labrador. The essentially comparable higher surface temperatures and low vertebral numbers on both north-eastern, eastern and south-western Grand Bank, and in the Gulf of Maine; the probability that intermediate surface temperatures are present at this time of year, associated with intermediate vertebral averages on the Northeast Newfoundland Shelf, are both in agreement with the expected relationships between temperature and vertebral number. In the Gulf of St. Lawrence where recruitment of young redfish is very intermittent, it is likely that surface temperatures in May and June of different years may vary enough to produce high vertebral numbers in certain low-surface-temperature years, and low numbers in high-temperature years.

The argument cannot be carried much further until more information on the surface water temperature is available for May and June and until the comparative larval extrusion periods over the area are known more accurately. A difference of two weeks in May or June will allow considerable differences in surface temperature. However, it is evident that, at the present level of knowledge, by far the best agreement between redfish vertebral numbers and an environmental factor is with surface temperatures in May and June. It consequently follows that the most likely stage for determination of redfish vertebral numbers in the North-west Atlantic is in the surface swimming larvae over 7–9 mm in length in May and June after their extrusion from the parent. On the other hand, over the whole area there is no very adequate relationship between vertebral number and August temperatures. Consequently it is probable that for most redfish larvae the plastic period for the determination of vertebral numbers is completed before August.

From the apparent relationship between vertebral number and temperatures of the surface water in the same areas, it follows that in most large areas populations of adult redfish are self perpetuated and that they develop from larvae produced by essentially local populations, or at least from larvae whose vertebral numbers are largely determined during the late spring/early summer plastic period by the surface temperatures in the general area occupied by the local adult population.

Summary

Vertebral numbers of mainly *mentella*-type redfish caught in 1947–1954 in the North-west Atlantic are compared. Vertebral averages, not including the urostylar half-vertebra, decline from about 30·0 off Labrador and in one West Greenland sample, southward along the Northeast Newfoundland Shelf to 29·1–29·2 on the north-eastern, eastern and south-western Grand Bank. Another line of declining vertebral averages runs from Labrador through a range of between 30·1 and 29·3 in the Gulf of St. Lawrence, to 29·1–29·2 on the Nova Scotian Shelf and to 29·0 in the Gulf of Maine.

The full range in vertebral numbers is from 28–31, the great majority of vertebral columns having either 29 or 30 vertebrae. In Labrador 95 % of the redfish have 30–31 vertebrae; at the southern extreme, in the Gulf of Maine, the percentage is only 3–5.

The closest relationship of vertebral numbers and environmental factors is a negative correlation with May–June surface temperatures. It is consequently inferred that the plastic period for the determination of vertebral number in the redfish extends to or occurs in the early larval pelagic stage, after extrusion from

the parent female. There is no correlation between redfish vertebral numbers and August surface temperatures, so that the plastic period must be ended before August.

On the south-west coast of Newfoundland and in the Gulf of St. Lawrence, vertebral numbers of small and of large redfish and average vertebral numbers of given samples often differ very significantly in the same area. In these areas the older redfish examined during this period have had predominantly 30–31 vertebrae and were developed mostly during the colder period before 1920. The younger redfish from the same areas often had the 29 vertebral number predominant and were developed in the later warmer period.

The distribution of redfish vertebral numbers indicates that there was little migration by these *mentella*-type redfish of the Northwest Atlantic.

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A.7

A Brief Survey of Soviet Investigations in Redfish *(*Genus *Sebastes)*

By
V. I. TRAVIN
Polar Institute of Marine Fisheries and Oceanography, Murmansk

Some information about redfish appeared for the first time in the works of Russian scientists, who had investigated the Barents Sea in the second half of the past century; see P. N. Danilevski (1862), N. M. Knipovich (1904, 1927), L. A. Breitfuss (1913), S. V. Averintsev (1924, 1927), T. S. Rass (1929), A. A. Shorygin (1933).

The data reported by the authors listed above are brief and incomplete, as until the late twenties of this century the Russian fishery had been operating generally along the Murman coast and on the Kanin Banks, where the redfish, as a rule, is rare. Only in the early 1930's did the Soviet trawler fleet start operating in the western Barents Sea, in the Bear Island area and in the open part of the central regions. As redfish began to appear more often in the catches, and with biological information accumulating, a great interest arose in this species. Since the beginning of this period a series of papers by Soviet scientists has been published, outlining more clearly certain aspects of the life cycle of redfish from the Barents Sea, so that now a fairly full picture of the biology of this fish is available.

Systematics

For a long time it was considered that only three redfish species lived in the Barents Sea: *S. marinus* L., *S. viviparus* Kr., and *Helicolenus dactylopterus* Delaroche. The latter two are of no commercial importance.

S. viviparus is very small and of low quality as a food fish. Its distribution is limited to a narrow strip along the western and northern coasts of Norway. *Helicolenus dactylopterus* occurs very rarely in the western Barents Sea, occasionally immigrating from more southern Atlantic regions. *S. marinus* has been considered the only redfish species in the Barents Sea, widely distributed in these waters, forming dense concentrations and being of a great significance to the fishery. Recently, however, observations made by fishermen and scientists revealed the fact that the redfish from the Bear Island Bank area is far smaller and more slow growing than that from the southern Barents Sea. Special investigations were carried out in the Bear Island area at different depths just after World War II, and a new species, *Sebastes mentella* Travin, was discovered, differing from *S. marinus* not only in the rate of growth but also with regard to several morphometric characters, depth range, areas of distribution and – as was established later (Sorokin, 1956) – "spawning" areas. The relevant data have been published in the thesis of V. I. Travin (1949) and in the form of a brief summary in the "Doklady Akademii Nauk SSSR" (Proc. Acad. Sci. USSR) (1951). It was assumed that *S. mentella* would become of great importance for the deep-water trawl fishery. This assumption has been fully justified by the development of fisheries on new grounds in the Kopytov area, in Icelandic waters and later in the North-west Atlantic.

Distribution

Redfish are distributed widely in the Arctic and in the North Atlantic. However, the data reveal that *S. mentella* is more characteristic of Atlantic waters than *S. marinus.* Thus *S. marinus* is distributed farther to the east and to the north than *S. mentella,* though their habitats sometimes overlap. In the Barents Sea, the 25°E meridian may be considered the eastern boundary of *S. mentella* concentrations suitable for a fishery; concentrations of *S. marinus* can be found up to the Goose Bank, 45–50°E; in smaller quantities it occurs as far as Novaya Zemlya. In the western Atlantic a successful fishery for *S. mentella* exists only up to the southern part of Labrador, the northern slopes of the Grand Bank of Newfoundland, and the western and southern coasts of Iceland. *S. marinus,* on the contrary, is found in fishable concentrations in the Davis Strait and off the East Greenland coast. This character of habitat of the two main redfish species, in the writer's opinion suggests a more ancient origin of *S. mentella.* During the glacial period, when the greatest part of the relatively shallow water area of the Arctic Basin, which is now the main habitat of *S. marinus,* was covered with ice, favourable conditions for this species could hardly have existed. At that time redfish must have inhabited deeper waters, where *S. mentella* shoals prefer to live nowadays. By the end of the glacial period, when relatively shallow water areas had become free from ice, redfish immigrated to such areas. The distribution of *S. marinus* seems due to such an immigration, followed by adaptation to the new life conditions. This is to be considered only as an assumption, to be confirmed by future investigations, particularly anatomical.

Migrations

The migrations present one of the main problems of fish biology, having a direct bearing on fishing and its distribution in time and space. The problem is particularly difficult regarding redfish migrations, because thus far no satisfactory methods of tagging have been developed. Nevertheless, analyses of the drift of the larvae, extent of the fisheries and the age, size and sex compositions of catches, provide a basis for a general scheme of *S. marinus* migrations in the Barents Sea (Maslov, 1944). This scheme still remains valid with only few corrections.

The redfish larvae, spawned off the north-west coast of Norway, drift with the branches of the North Atlantic Current northwards (in the direction of Bear Island and Spitsbergen) and eastwards (along the coast and towards Novaya Zemlya). Many larvae seem to perish, meeting unfavourable environmental conditions: young redfish are found commonly in the western Barents Sea, while in the eastern region, to which the young of almost all species spawning in the Lofoten area are carried, young redfish occur only very rarely. In the early years of the life of the redfish the migrations are limited to the region to which it has been brought by the currents: in winter the young migrate to the warmer deep water areas, in spring and summer to shallow water regions. As the young redfish grow up, the migrations of the immature fish from the south-western part of the central areas of the Barents Sea — and Hopen in the warm season — become more extensive and extend to the western regions and Bear Island, where they contribute considerably to the winter/spring concentrations. The most extensive migrations are those of mature redfish; essential differences exist between the migration routes of males and females. The females migrate from the "spawning" areas with the warm currents to the north and to the east, meeting the male shoals in the Bear Island area and at the northern coast of Norway. Then they travel together to the very utmost boundaries of their habitat. Here feeding and copulation take place. With the onset of cooling, male and female shoals begin their return migrations. By winter, the shoals reach the areas of hibernation of the immature male redfish. The latter remain there till spring, while the females, in whose ovaries fertilization of the eggs is going on, continue their way to the "spawning" places. Thus, for a certain period the shoals of mature males and females live separately and females predominate in the "spawning" areas. A similar migration trend is characteristic for *S. mentella,* with the only difference (V. P. Sorokin) that the movements take place in the westernmost part of the Barents Sea, and liberation of larvae occurs in the deep area south-west of Kopytov.

Unfortunately, there are as yet no data indicating any relationship between the migrations of the Barents Sea redfish and those from Iceland and other southern Norwegian Sea areas. Drift of the larvae, observed on sections across the Norwegian Sea, makes such a relationship quite possible.

Reproduction

The reproduction process is similar for all *Sebastes* species. This appears from Schmitt (1944) and Sorokin (1956,1959). Schmitt has studied the sexual cycle of *S. marinus* females, the embryonic development of the eggs, spawning, geographic distribution of pelagic larvae and their development during the drift. Sorokin collected much material, particularly of histological data, so his studies were naturally more exact and more complete, especially as to copulation and fertilization of eggs. He has also made a detailed study of spermatogenesis in *S. marinus.* The singularity of the reproduction process of redfish lies in the consecutive development of gonads of males and females. The males mature in autumn, when the eggs in the ovaries are far from being ripe. Copulation occurs in areas of summer-autumn feeding of the mature redfish and the spermatozoa remain inactive in the ovaries of the females until the eggs ripen. Then a change in the pH of the ovarian fluid brings about an increased activity of the spermatozoa and gametic syngamy takes place. Then follows a normal egg development, hatching of the embryos in the body cavity, and liberation of the larvae into the water.

The different migration pattern of males and females and the formation of unisexual shoals after fertilization, is fraught with the danger of a one-sided fishing of one or the other sexual group, as observed for instance in the fisheries on the Kopytov ground, where only males were subject to fishery. A disturbance of the normal sex ratio may result, which could affect reproduction. Thus, preliminary data, collected during recent years by Sorokin on the feeding grounds during the copulation period of *S. mentella,* reveal a considerable decrease in the percentage of males.

Growth and age

Soviet investigators determine the growth of redfish from scales taken from the region of the pectoral fins. The scales are preserved, washed in ammonia solution and examined by means of a microprojector with a magnification of 35 times. If necessary, the annual rings are used for back calculation of growth-rate. The length of the fish is taken from the end of the snout to the end of the caudal fin, using 2 cm groups. Mass measurements and age sampling are done on a large scale in the areas of the most intensive fisheries, so that the samples represent the actual catch. In recent years, in connection with the differences in opinion as to the growth and age of the redfish, samples of the young of redfish have also been studied.

Soviet scientists (Smaragdova, 1936; Veschezerov, 1944; Travin, 1951, 1952; Surkova, 1957) agree on the slow growth-rate of all *Sebastes* species; the maximum increase in size during the first year of life; the late maturing and the longevity of the redfish (Surkova). According to these data, both *S. marinus* and *S. mentella* have approximately the same growth-rate during the first 5–7 years, owing to similar living conditions during this period. When they pass to the demersal mode of life, which presents essentially different conditions for each species, the growth-rate of *S. mentella* lags behind considerably. During the first year both species reach an average length of 6–8 cm (according to observations) with a full length range of 4–10 cm.

Feeding

Investigations on feeding behaviour also present considerable difficulties, since most of the fish discharge their stomach contents during hauling. Despite this, many years of continued sampling and biological analysis of catches have furnished sufficient information. The most detailed and complete data concerning feeding behaviour of redfish are reported by Boldovski (1944), and are confirmed by later observations.

Considerable differences occur in the feeding habits of the small, immature and adult redfish. The former, inhabiting the free water, feed on small plankton organisms, which are practically absent from the food of adult fish (small crustacea — Copepoda, Hyperiida — planktonic worms, e.g. *Sagitta*) and to a lesser degree, on shrimps; fish are rarely found in the stomachs. No strong seasonal fluctuations in the feeding of young redfish are observed.

The main and favourite food of adult redfish is fish (herring, capelin, gadoid fry make up to 65 % of the stomach contents; krill make up to 21 %; followed by large plankton organisms, such as shrimp, Ctenophora –about 11 %). Bottom animals are only rarely found in the stomachs and seem to be a rather accidental food. Owing to the extensive migrations of the adult redfish, their feeding shows considerable seasonal and regional variations, determined by the seasonal and geographical distribution of food organisms. Nevertheless, judging from the feeding behaviour, the redfish does not seem to be a typically demersal fish, as for instance are haddock or flatfish, but a bathypelagic one. In this connection, one can easily explain the considerable fluctuations in catches of redfish, not infrequently observed within the 24 hours, as due to diurnal vertical migrations in search of food. This observation justifies the use of the upper otter boards (kites) on the trawl's headline to enlarge their vertical opening.

As to the biology of the redfish in the North-west Atlantic, there is not yet sufficient information. However, the data available suggest that in many biological aspects they resemble the redfish of the Barents Sea. Also in the ICNAF area, both *S. marinus* and *S. mentella* are found, but relationship with the Barents Sea species can hardly be established without special investigations. The reproduction mechanism and even the periods of liberating larvae, as well as the age composition of the stocks and the feeding behaviour, seem to be similar. The migrations of both species have been little investigated. This presents a noticeable gap in our knowledge of a problem having a practical importance.

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A.8

Sebastes viviparus (Krøyer) and the Redfish Problem

By
G. C. TROUT
Fisheries Laboratory, Lowestoft

The controversy over the interpretation of the redfish otolith structure became crystallized at the 1956 Biarritz Meetings. (See Convenor's and Meeting Reports, 1958). Kelly on the one hand, supported by earlier work of Bratberg (1956), produced seasonal evidence that only one opaque zone was laid down each year and that a full year's growth was composed of one opaque and one hyaline zone. Kotthaus, on the other hand, maintained that the opaque summer growth was laid down as a complex structure and that a number of opaque and hyaline zones had to be grouped together to count as a full year. Even after an exchange of material, during a "workshop meeting", neither worker would agree to a common interpretation.

With this in mind the writer consulted the only redfish collection in the U.K. known to contain specimens from the American coast. Through the kindness of Mr. N. B. Marshall of the British Museum of Natural History, specimens sent by the Smithsonian Institution from the Gulf of Maine in 1879 were examined; so also was the original collection of Collett's *S. viviparus* dated 1887.

The latter proved of value since it showed the variability of the pre-opercular spines of *S. viviparus*. This character was one of the most important used by Andriiashev (1954) in his key differentiating *S. viviparus* from other European species. The spines of Collett's specimen from the Christiania Fjord were small, the lower two, 4 and 5 (Ginsburg, 1953) being almost vestigial. The tips were, none the less, directed backwards towards the tail. Samples collected by the "Ernest Holt" from the NW Norwegian coast had considerably larger spines but of these the lower spines were also directed posteriorly.

The direction of the lower spines, 4 and 5, was examined closely in the 1879 specimen from the Gulf of Maine. The fish was in reasonable good condition, apart from some damage to the eyes and tailfin. The head armature was well developed, and the pre-opercular spines were long and thick. The tip of No. 4 pointed downwards and backwards but No. 5 spine had damaged tips on both sides of the head. The knob of the lower jaw symphysis was more accentuated than in the European *S. viviparus* but was downcurved and more rounded than the beak of the European *S. mentella.*

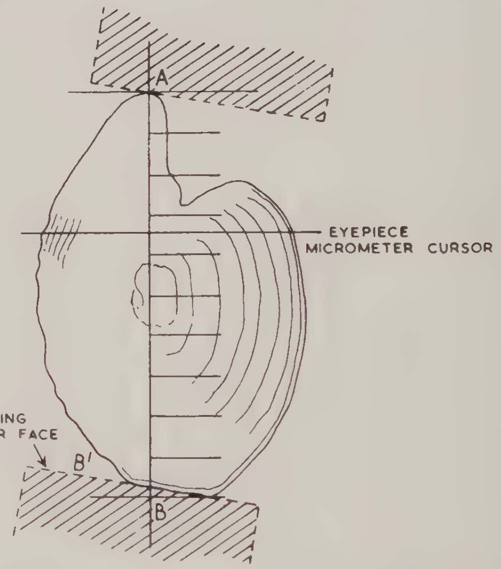

Figure 1. Methods of measuring redfish otoliths.

Mr. Marshall generously allowed the otoliths of this specimen to be removed, on the offchance that, despite an 80 year sojourn in alcohol, it might be possible to determine its size and shape and also what opaque zone structure lay inside. The left otolith only was removed. It was large and although it was much stained, it showed, after clearing in xylol, a ring structure which in certain portions looked somewhat like that of *S. viviparus* of the Norwegian coast population.

Now a feature of the samples of *S. viviparus,* caught by the "Ernest Holt", was the noticeably larger size of their otoliths for a given size of fish, compared with those of *S. marinus.* It was thought that this qualitative difference would be most simply and quantitatively stated by means of otolith length measurements. Otolith widths were also recorded so that an index of shape could be obtained.

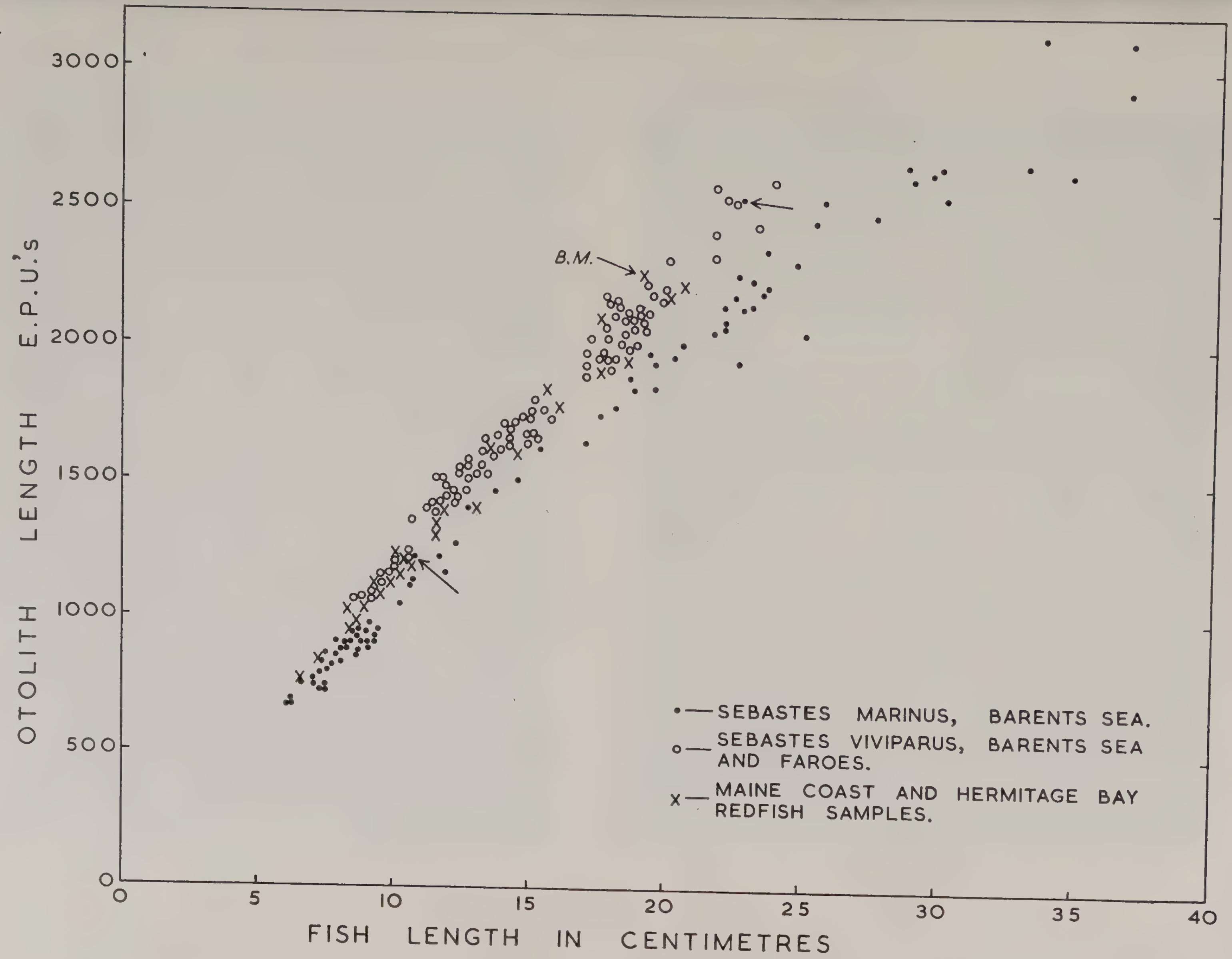

Figure 2. Fish length/otolith length relationship for *Sebastes* spp. from different areas.

Two methods of measurement were used. The smallest otoliths were measured on a low powered binocular microscope with a Ramsden Screw Drum Micrometer (Figure 1). This has (i) a scale through the centre of the field, (ii) a base line at right angles to the scale, and (iii) a cursor which can be moved from the base line to any desired position along the scale. Otoliths longer than the scale were measured by an engineering or workshop micrometer and their measurements, made in millimetres, were merely converted to eyepiece units. Whilst the eyepiece micrometer could be set up to measure the maximum length A B, the workshop micrometer exerted a pressure on the otolith which tended to twist it into such a position that a slightly different length was measured – A B^1 The variability of the angle of the flat at the posterior end of the otolith also added to the spread of the observations obtained by this method, which thus, on the whole, gave an underestimate of otolith length for the larger fish of both species, i.e. those above approximately 15 cm.

Measurements of *S. viviparus* samples from both the Norwegian coast and the Faroe Islands were plotted against the length of the fish measured to the nearest millimetre (Figure 2). It will be seen that the points fell on a common curve, despite the fact that the curve was based upon fish from two populations, with two different growth-rates and from areas with very different temperature and environmental regimes. Such a curve may be said to indicate a species or specific relationship.

Otoliths of juvenile *S. marinus*, from a number of positions on the Spitsbergen Shelf from SW and W of Bear Island, from Hornsund Spitsbergen, from Hopen and from the Norwegian coast, were measured and the results plotted in the same way. These observations lay on a different curve and showed very little overlap with the *S. viviparus* measurements; two observations are arrowed in Figure 2. Left hand otoliths only were used, from both species.

The length of the single large otolith of the British Museum Gulf of Maine specimen fell within the *S. viviparus* observations. (This single observation is labelled B.M. in Figure 2.) It is possible that damage to the tail led to an underestimate of the fish's length — by a millimetre or two only.

Mr. George Kelly of the Woods Hole Biological Laboratory, kindly sent a small sample of redfish otoliths collected from the Gulf of Maine and from off Gloucester, Massachusetts. Measurements of these appear in Table 1, but unfortunately a number of the otoliths were smashed in transit and only 19 were usable.

Table 1. Rosefish from Gulf of Maine and from Gloucester, Massachusetts

Fish length group (cm)	Otolith measurements (in eyepiece units)	Mean otolith length (in e.p.u.)
11	1346 × 807 : 1462 × 937 : 1214 × 794	1341
13	1630 × 1067	1630
14	1546 × 1012 : 1576 × 960 : 1547 × 992	
	1640 × 1070 : 1677 × 1078: :1614 × 1055	1600
15	1869 × 1202 : 1844 × 1214 : 1864 × 1175	1859
17	2041 × 1250 : 1851 × 1253 : 1843 × 1246	1912
18	1949 × 1284	1949
19	All smashed	–
20	2382 × 1598 : 2148 × 1429	2265

As the fish lengths were in centimetre groups the otolith measurements were plotted at the half centimetre above. It will be seen that all observations derived from this sample lie close to the *S. viviparus* curve. It should also be noted that the detailed structure and appearance of the whole otoliths, in addition to their shape and relative size, are strikingly comparable to those of the European *S. viviparus*. (Kelly, 1959, and Trout, this volume) (see Figs. 3 and 4). They are quite unlike those of the European *S. marinus* depicted by Kotthaus (ibid.), either in gross form or microscopic structure.

Of interest is the regression of otolith length on width for *S. viviparus* from the northern Norwegian coast and from the Faroe Islands. The plotted values from both populations lie on the same straight line and show little spread (Figure 5A). Values derived from the Gulf of Maine material (Table 1) (and, subsequent to the Symposium, from Hermitage Bay material lent by Mr. E. J. Sandeman, St. Johns) also indicate a closely similar otolith length/width relationship to *S. viviparus* and one which is significantly different from the European *S. mentella* (pecked line). Figure 5B shows the values of the small material of *S. mentella* compared with *S. marinus* from Barents Sea samples. Both species show a much greater variability of otolith shape than does *S. viviparus* or the N. American fish. This, together with the relative size difference of the otolith for a given fish length, suggests a species difference. It does not, of course, resolve the problem of systematics, but the implication is that the North American redfish is not *Sebastes marinus*. Its otolith size and shape also differs from the NE Atlantic *S. mentella*.

Since the nineteenth century controversy, well documented by Gill (1863) and Lütken (1876), other writers have questioned the specific name used for the redfish or rosefish of the American coast. Jordan and Gilbert (1882) considered that *S. viviparus* was encountered on the American coast, as far south as Cape Cod. Tåning (1949) states that the small "...American Rosefish seems to be distinct from the two European species ... but in some characters more closely allied

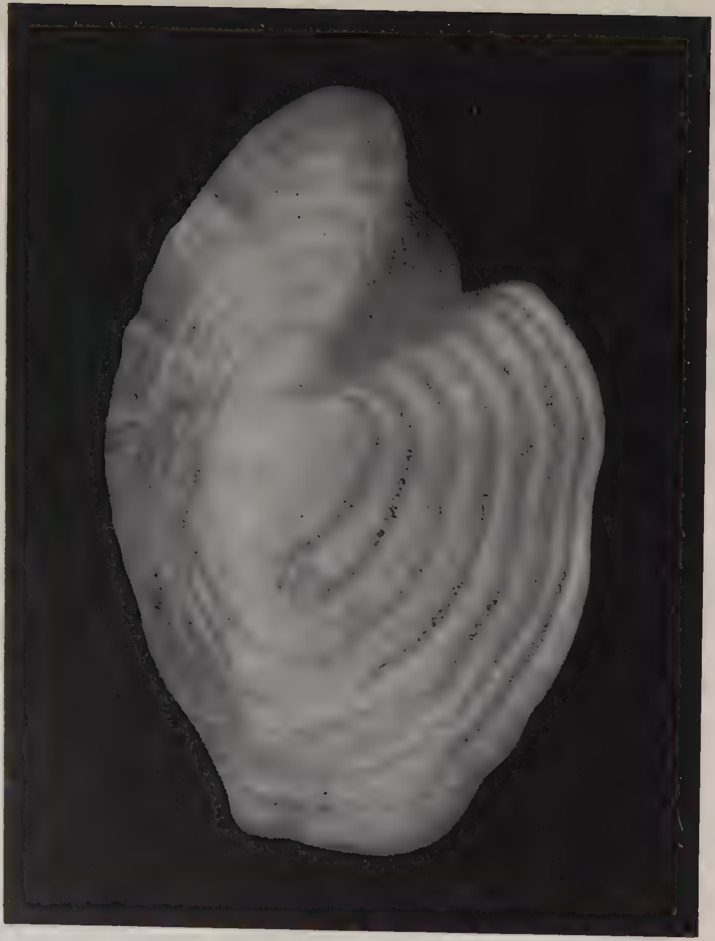

Figure 3. Otolith of *Sebastes viviparus* from the Norwegian coast (fish length: 11·7 cm).

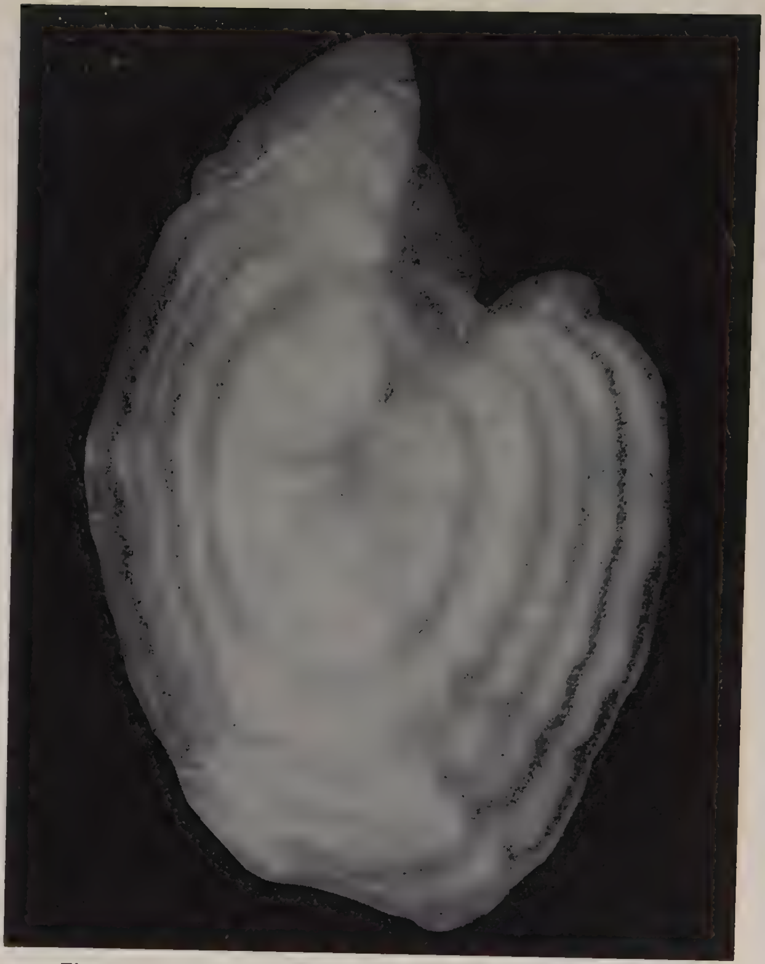

Figure 4. Otolith of American rosefish from the Gulf of Maine (fish length: 20 cm).

Figures 3 and 4 are not to same scale.

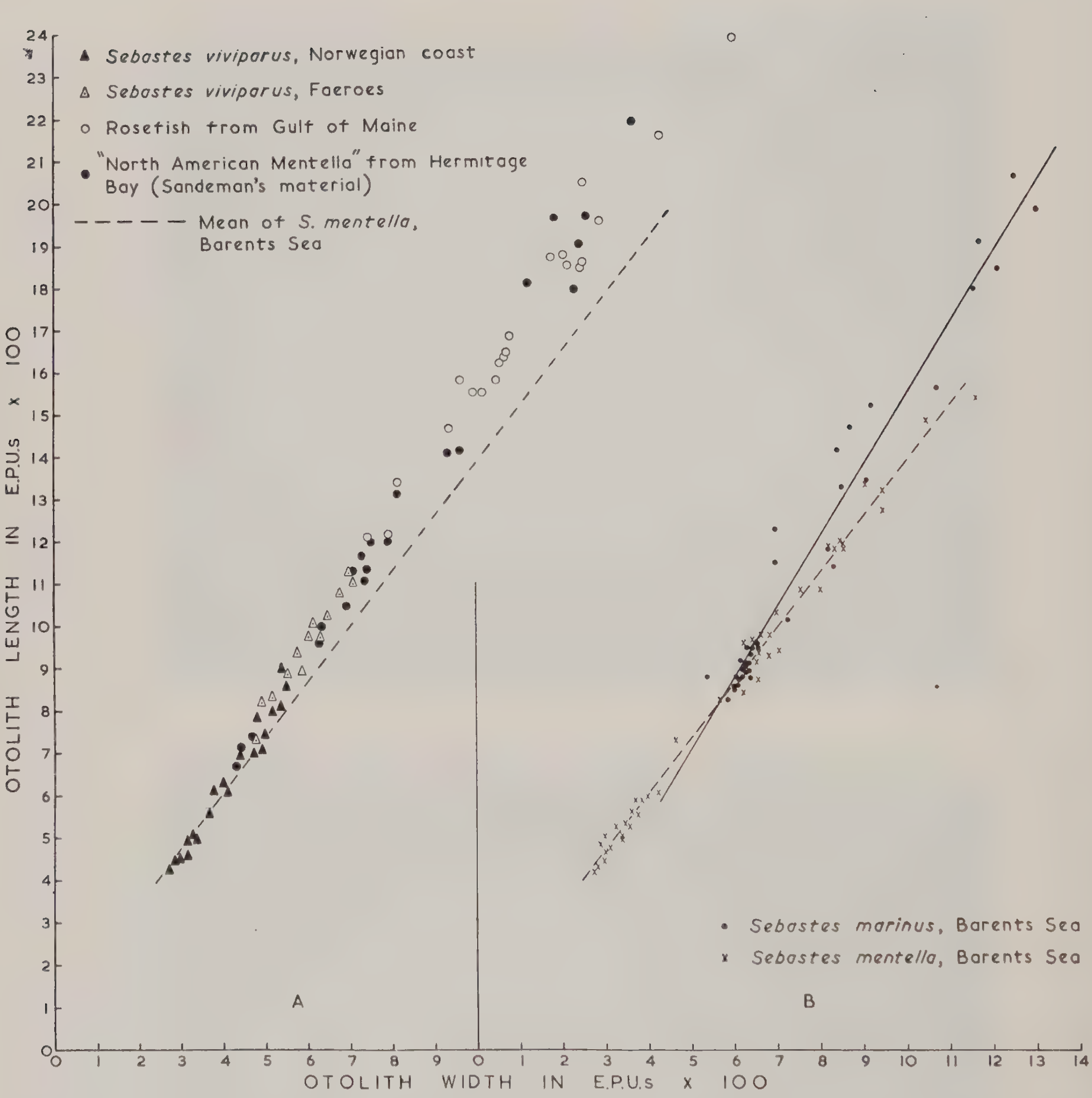

Figure 5. Regressions of otolith length on width. (Compare with fish length/otolith length relationship shown in Fig. 2.)

to the small Redfish (*Sebastes viviparus*)..." — at that time only *S. marinus* and *S. viviparus* were recognised — whilst Travin (1952) considers the species living in the Gulf of Maine to be *S. viviparus,* but gives no reason for this conclusion.

The data put forward in this paper is additional evidence supporting Tåning's view that the American coastal Rosefish is a form more closely related to the European *Sebastes viviparus* and is not *Sebastes marinus.* The similarity of growth-rate of the small European redfish (Trout, this volume) lends additional weight to this evidence.

Serological techniques appear to offer the best solution to the problem of exact relationship between the American coastal form and *S. viviparus* and also the other forms, but the inference to be drawn from the observations contained in this paper is that one major problem of the controversy may possibly be removed, because it arose from a comparison of material from two different species.

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B.1

An Immunological and Chromatographic Study of *Sebastes marinus* (L.) and *Sebastes mentella* Travin

By
FERGUS J. O'ROURKE
University College, Cork, Ireland

Some time ago Mr. G. C. Trout of the Lowestoft Laboratory asked if it would be possible for my department to undertake an investigation of the relationship between *Sebastes marinus* (L.) and *S. mentella* Travin using the serological methods described by Boyden and Defalco (1943) and used in a recent study of the genus *Gadus* (O'Rourke, 1959). As Mr. Trout agreed to collect and send us the blood we were happy to undertake the project. After some time, however, we found that it was very difficult to produce satisfactory antisera for use in photronreflectometric studies, in the rabbits available to us. We therefore tried Ouchterlony (1949) plate studies and Consden and Kohn's (1959) cellulose acetate immuno-diffusion method.

We also became interested in the possibility that the mucus of the two forms of *Sebastes* might differ as it does in other fishes. It had recently been shown in our laboratory that the mucus of fishes, like that of snails (Wright, *et al.*, 1957) was, for the species investigated, a species specific characteristic (Barry and O'Rourke, 1959). Mr. Trout was able to supply us with the gill mucus of both *S. marinus* and *S. mentella* and we studied the chromatographic characteristics of both forms.

This paper deals with the results of these investigations.

A. Immunological Studies

(a) Photronreflectometric curves

The photronreflectometer was devised by Libby (1938) for the measurement of the turbidity produced by the interaction of antigen-antibody (AnAb) systems. The instrument has been much used in the study of relationships between species (Boyden and Defalco, 1943). It has the advantage that the entire range of interactions between all the antigens and antibodies in the system studied are measured over the full range from antigen excess to antibody excess. In our studies serum from *Sebastes* has been used to inject rabbits which were used as the antibody producers. The serum was collected and sent to our laboratory merthiolated (i.e., with sodium ethyl mercuri thiosalicylate *Eli Lilly,* 1 in 1,000 added to give a final concentration of 1 in 10,000), where, after centrifugation, it was kept at 4°C. Despite a series of courses of injection given to a number of rabbits we were able to produce only one anti-*Sebastes* serum which gave satisfactory photronreflectometric curves. This was an anti-*mentella* serum R 918 produced in a male albino rabbit which had a series of subcutaneous injections of 0·5 ml of *S. mentella* serum on three alternate days in July 1958 but failed, at that time, to produce a suitable antiserum. The animal was kept a year and had a further course of three subcutaneous injections in the neck region at five day intervals in July 1959. The first injection of this course consisted of 0·75 ml of serum, the other two of 0·5 ml. The animal was bled out two weeks after the last injection. The antiserum gave a homologous photroner curve sigma tau value of 617. The heterologous curve using *S. marinus* serum gave a sigma tau value of 502, indicating an 81 % affinity between the two forms (Fig. 1). Unfortunately, we have not been able to get a satisfactory reciprocal curve.

(b) Ouchterlony agar diffusion studies

In the Ouchterlony agar diffusion technique antigen and antibody are put into cups cut out of an agar plate so that the antigen and antibody diffuse towards each other, forming zones of precipitate along the lines of optimal proportions. The method has the advantage that the two or more antigen mixtures can be compared simultaneously. Where two antigens in separate cells are identical the AnAb precipitation lines fuse, whereas if they are distinct species of antigen the lines cross unaffected (Fig. 2).

Again, we were able to use only anti-*mentella* serum

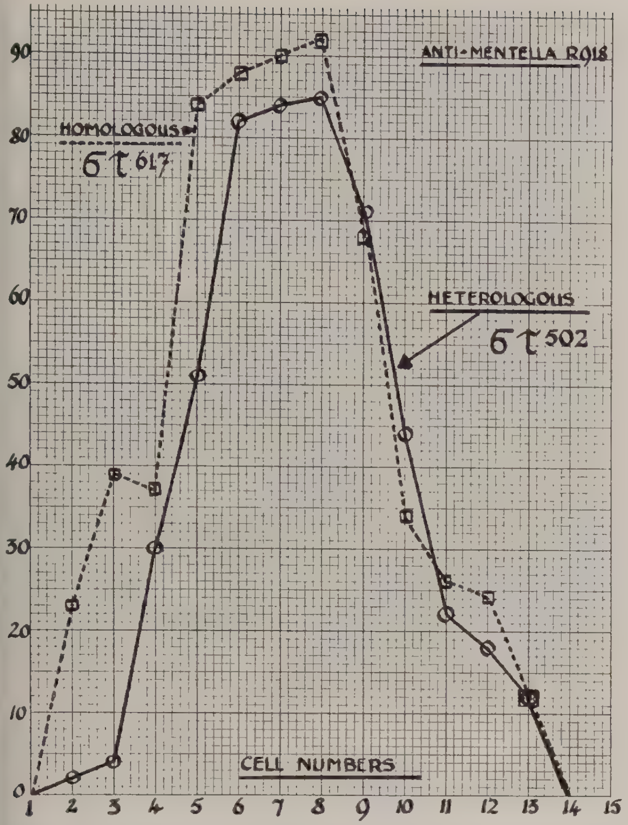

Figure 1. Photroner curves produced by interacting anti-*mentella* serum R 918 with *Sebastes mentella* serum (dotted line) and with *Sebastes marinus* serum (solid line).

R 918 for Ouchterlony agar diffusion studies. The results obtained by allowing diffusion for 45 hours at 24°C by the Ouchterlony method are shown in Figure 3. It will be seen that the homologous reaction *mentella*/anti-*mentella* gave two clear AnAb reactions whereas the heterologous reaction gave only one band. By allowing diffusion to continue for 65 hours we have found that there is, in some cases, a possible third reaction. Paper electrophoresis of both sera, with the standard veronal buffer at pH 8·6 with 0·4 mA per cm strip width for 14 hours followed by staining with either nigrosine WS or lissamine green, gave us two clear cut fractions and a somewhat fainter third. With Kohn cellulose acetate electrophoresis using veronal buffer at pH 7·9 and a current of 0·2 mA per cm width for two-and-a-half hours we have had four fractions with *marinus* serum. We have had some curious Ouchterlony reactions which require further study.

(c) Consden-Kohn cellulose acetate immuno-diffusion

This technique is a modified Ouchterlony method described recently by Consden and Kohn (1959). Cellulose acetate membrane replaces the agar gel, and microlitre qualities of antigen and antiserum are used instead of millilitre volumes, thus conserving antisera which may be difficult to produce. The results obtained with anti-*marinus* serum R 936 and anti-*mentella* R 918 are shown in Figure 4. Anti-*marinus* R 936 was

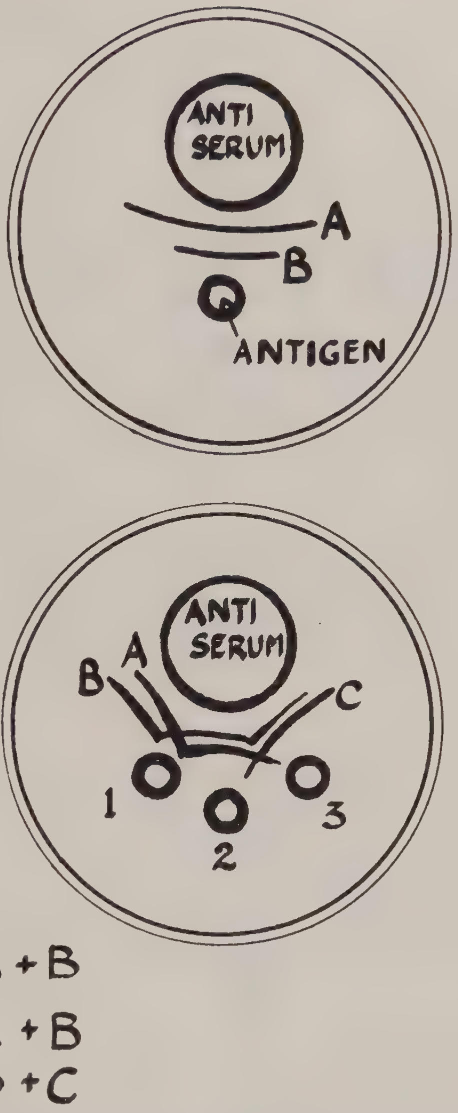

Figure 2. (Upper) Diagram of the Ouchterlony type of reaction given by an antiserum to A and B antigens when a mixture of A and B are placed in the antigen cup and the reaction allowed to occur.
(Lower) Diagram of the Ouchterlony type of reaction given by an antiserum to A, B, and C antigens when three different antigen mixtures are reacted with it. Both cups 1 and 2 contain A and B but in different relative proportions. Cup 3 contains antigens B and C. Note that since antigen C is not identical with A it crosses the A-anti-A line of precipitate. Since antigen B is present in all three cups the B-anti-B lines of precipitate fuse.

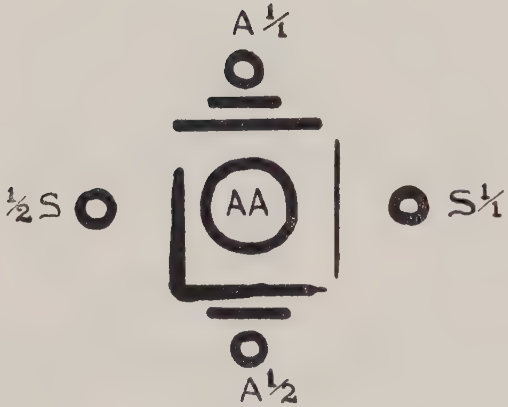

Figure 3. Ouchterlony plate reactions given by anti-*mentella* serum R 918 (central cup AA) when reacted with *Sebastes mentella* serum upper and lower cups and *Sebastes marinus* serum right and left cups. The fractions indicate the concentration of the serum ($^1/_1$ = diluted with an equal volume of normal saline).

produced in a female albino rabbit by giving fo weekly subcutaneous injections of 1·0 ml in the ne and then the animal was bled out nine days after tl last injection. It will be seen that in each case tv bands are found in the homologous reaction but on one in the heterologous. There is a suggestion that tl dense inner band may be in fact a complex and that least some of the antigenic components of this bar may be common to both forms. Further investigatio are clearly warranted and are planned.

(d) Conclusions from immunological studies

The serological studies show clearly that the tv forms *S. marinus* and *S. mentella* are immunological distinct. The degree of affinity as shown in the ph troner study, viz. 81 %, is less than that found in tl well differentiated haddock *G. aeglefinus* L. ar pollack *G. pollachius* L., which show a 90·5 % affini (O'Rourke, 1959). The immuno-diffusion studi suggest that some antigenic components may be eith common to both forms or very closely similar in the antigenic properties. Clearly future work on the problems would be advisable.

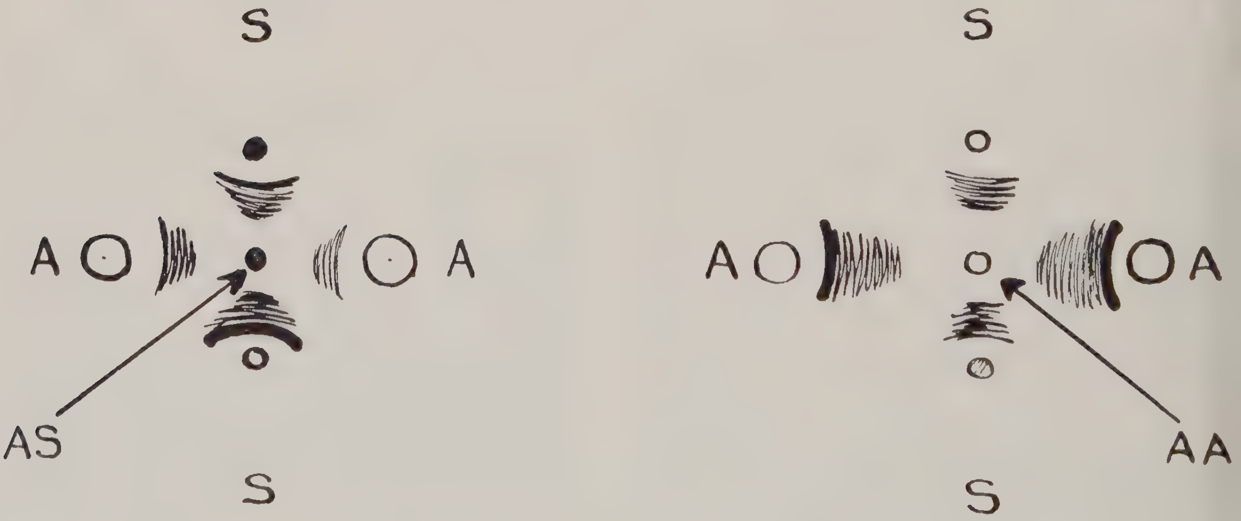

Figure 4. Consden Kohn immuno-diffusion studies with anti-*mentella* serum R 918 (left centre AS cup) and anti-*marinu* R 936 (right centre AA cup). In both reactions undiluted *Sebastes* serum was used in the peripheral spots; *marinus* ir upper and lower positions, *mentella* on right and left sides. The strongest most peripheral band in the homologous reaction (upper and lower on left and left and right on right) are Ponceau C positive whereas the diffuse multiple AnAb inner banc reactions are only stained by nigrosine.

B. Chromatographic Studies

(a) Experimental

Barry and O'Rourke (1959) have shown that fish mucus shows species specific characteristics, as Wright *et al.* (1957) had previously found for snails. The gill mucus of the two forms of *Sebastes* were studied using ultraviolet fluorescence methods and also by ninhydrin staining of Kawerau chromatograms, after running in the standard butanol acetic acid and phenol ammonia and phenol water solvents.

Mucus from *Sebastes marinus* and *Sebastes mentella* produced similar fluorescent patterns after running with butanol acetic acid and showed eight identically coloured bands after treatment with ninhydrin. However, on viewing under ultraviolet light while still wet at the end of a run in phenol ammonia solvent, the diffuse outermost band (i.e., the band with the highest Rf value, viz. 0·75) is split in the former species by an evanescent absorption band not seen in the latter. After drying, the split band of *marinus* is no longer detectible as it is replaced by a single diffuse band as in *mentella.* Ninhydrin staining of the chromatogram produced by running in phenol ammonia gives ten identically coloured bands in both species. Running in phenol water gives two fluorescent bands with *marinus* and only one with *mentella*; the extra band in *marinus* has an Rf value of 0·21.

The fluorescent band pattern after phenol ammonia and butanol acetic varies with the sample, in that we have never had more than three bands with any one specimen of mucus from either *marinus* or *mentella,* but in all six different bands have been found in *marinus* and only five in *mentella.* The fluorescent bands are always faint, so that it is sometimes difficult to decide whether or not a band is present, and when there is doubt we count only clearcut bands. We, therefore, feel the total of five or six may well be the normal pattern of every fish, but that in some cases the bands are too faint to be detected with certainty.

(b) Conclusions from chromatography

The mucus of both forms differ on chromatography and this suggests that the two forms may well be separate species.

C. Conclusions

Two immuno-diffusion techniques, photronreflectometric measurements and two separate methods of chromatography provide evidence of biochemical specificity of *Sebastes marinus* and *S. mentella.* The degree of distinctness is such that we may consider the two as distinct although probably sibling species.

Acknowledgements

We are grateful to Mr. G. C. Trout who provided the sera and mucus used in these studies; to the Medical Research Council of Ireland which purchased for us the photronreflectometer and which gives a grant-in-aid to Mr. J. M. Barry, B.Sc., who helped with many of the experiments. We should also like to thank Miss Jacqueline Doyle and Miss Julia Vaughan, students in the Department who generously worked in the laboratory over the vacation.

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B. 2

A Biochemical Contribution to the Redfish Problem*)

By

HEINZ SCHAEFER

Biologische Anstalt Helgoland

In recent years biochemical analysis has joined the ranks of conventional methods of systematics. In this way, for example, Plouvier (1955) when searching for the occurrence of sorbitol in the Rosaceae, found valuable pointers to the inter-relationship of some plants, the systematic state of which was formerly a controversial question. This analysis and many others in botany and zoology showed that systematic groups are often characterized by the occurrence of certain substances.

In this respect the study of nitrogen compounds seems to be particularly promising, since every species contains specific proteins. Thanks to the development of paper chromatography, a method is available by which these problems can be followed with a relatively small expenditure of material and time. Several authors (Micks, 1957; Buzzati-Traverso and Rechnitzer, 1953, and others) squashed complete insects or pieces of fish muscle on the chromatography paper and produced patterns of ninhydrin positive substances to which the amino acids belong. These patterns proved to be specific for the individual species. The closer the relationship between the species, the smaller were the divergences to be seen on the paper chromatograms. Buzzati-Traverso (ibid.) believed, however – the visible spots on the chromatograms were not identified – that there are substances other than amino acids which are predominantly responsible for the differences between the species. The same belief was expressed by E. H. Dannevig (1956), who distinguished various sub-species of cod by such a method.

B. Ranke (1956) of the Bramstedt-school, worked with another method, that is, by means of alcoholic extracts from fish muscle, identifying the spots by means of two-dimensional paper chromatography. He concluded that the species dealt with could be distinguished, above all, by the occurrence of varying quantities of some free amino acids. His investigations were based on the work of Florkin (1956) who assumed a specific composition and a specific average concentration of the free amino acids in the muscle tissue for the individual species, particularly invertebrates.

The results hitherto reached regarding the species specificity of the pattern of free amino acids in the muscle gave the impetus for dealing with the muscle tissues of redfish, using Ranke's method (1956). Since Lundbeck (1940) had reported on the existence of an unknown form of *Sebastes*, later described as *Sebastes mentella* Travin (Travin, 1951), numerous morphological and ecological features have been described which allow this type to be distinguished from the well known common redfish, *Sebastes marinus* L. (Kotthaus, 1952, 1959). Certain characteristics suggest that these two types are true species (see e.g. Trout; Templeman and Sandeman; O'Rourke, this volume). The purpose of the present investigation was to establish whether or not differences are to be found in the pool of the free amino acids in the skeletal muscle of both *Sebastes marinus* and *Sebastes mentella*.

Material and Methods

During the research expeditions of the R/V "Anton Dohrn" in the international Geophysical Year 1958, samples from freshly caught redfish were collected at various trawl stations between Iceland and Greenland (Fig. 1). These muscle samples were immediately homogenized and preserved by the addition of ethanol and a few drops of chloroform. Later on they were analysed by means of two dimensional paper chromatography. In the first analyses the spots of the free amino acids visible on the chromatograms were arranged into five groups of concentration, from very weak to very strong, according to the size and colour intensity of the spots. From each muscle extract a quantity containing 0·1 mg Kjeldahl-nitrogen was placed on the chromatogram paper. On this basis a preliminary comparison of the quantities of the individual amino acids occurring in the different specimens was possible. It was seen that the quantities of some amino acids were different in *mentella* and *marinus*.

In order to confirm this finding a more exact method was applied. The concentrations of some free amino acids were determined according to Bode *et al.* (1952). The chromatograms were first sprayed with ninhydrin and then with a copper solution. The copper complex

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* Dedicated to Professor Kändler of Kiel University on his sixtieth birthday.

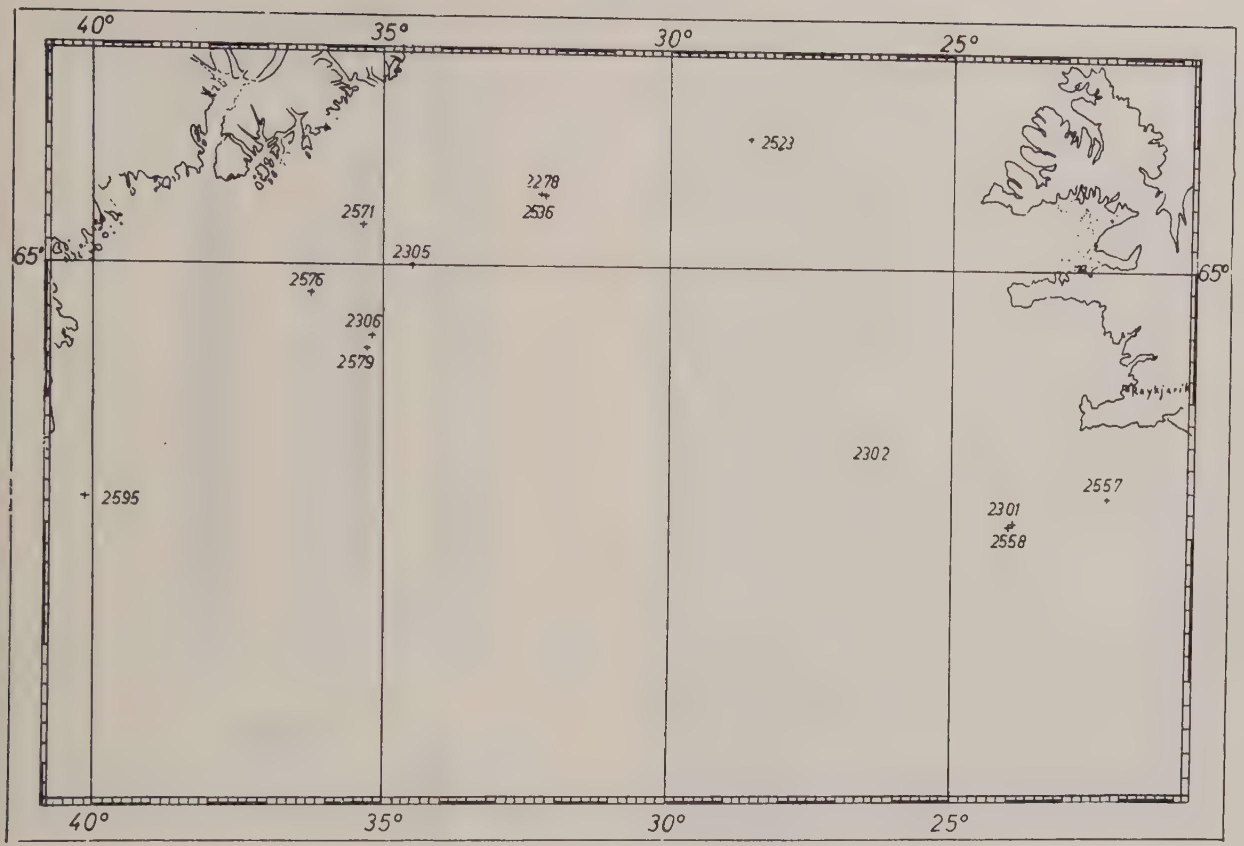

Figure 1. Trawl stations for redfish.

which formed on the spots of the amino acids was then eluted and measured at a wave length of 504 mμ. Some amino acids could not easily be separated. In these cases two substances with the nearest Rf-values, (glycine-serine, alanine-threonine) were determined. Proline was detected with the Folin's reagent and the content in the spots compared with spots of known concentrations. Using Bode's method determinations were also made of the total quantity of the ninhydrin positive substances to which, in the case of redfish, the amino acids, a peptide PR (Ranke, E. and B., and Bramstedt, 1955) and some unidentified substances in very weak concentrations, belong.

Results

In the qualitative pattern no difference is to be seen between *marinus* and *mentella* (Fig. 2). The two types contain the same free amino acids. There are some spots which have not yet been identified, but they occur in such small concentrations that it is not possible to detect them in all the specimens.

The content of total nitrogen extract (Fig. 3) is nearly the same, but the amounts of the ninhydrin positive substances differ in the two types. *Marinus* seems to contain about 30 % more ninhydrin positive substances than *mentella*. This was observed in both winter and summer samples.

The average values of some free amino acids are shown in Figure 4. The content of glycine-serine and of proline is lower in *mentella* but the content of glutamic acid and alanine-threonine is somewhat higher. Samples of the *marinus* type caught in winter contain less alanine-threonine than those obtained in summer.

It does not seem possible, however, to justify a comparison of fish caught at different stations, since in the paper presented at the Special Meeting of the IGY (Schaefer, 1959) it was shown that the individuals of a given species which come from different fishing grounds display some considerable variations in the relative concentration of free amino acids. For this reason only specimens of the two redfish types which came from the same haul were subsequently compared. The results of three stations are recorded, as follows:–

For the ninhydrin positive substances, clear differences existed between *marinus* and *mentella* only at station 2579 (Fig. 5). Here, the amount of these substances in *mentella* was very small.

At the winter station 2305 (Fig. 6) more glutamic

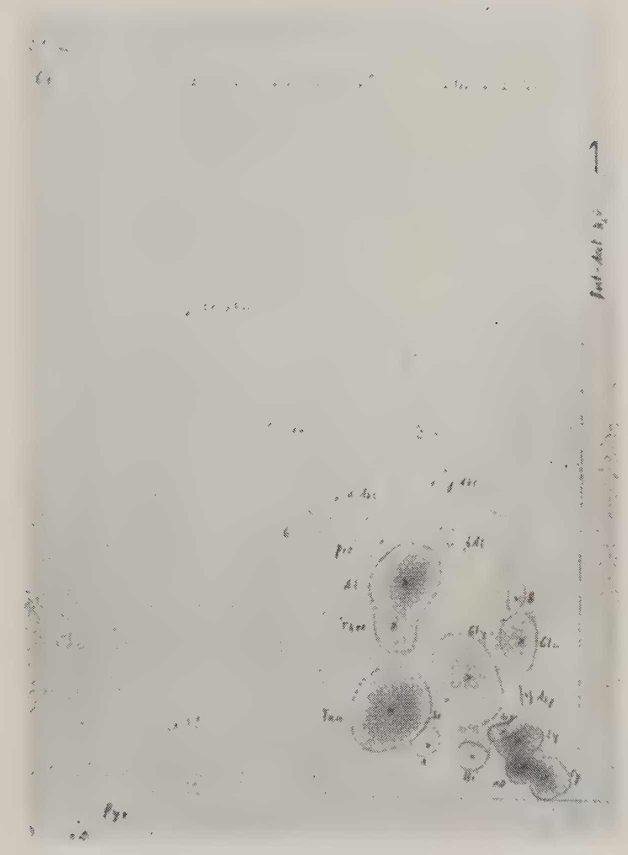

Figure 2. The pattern of the free amino acids in the muscle of *Sebastes marinus*.

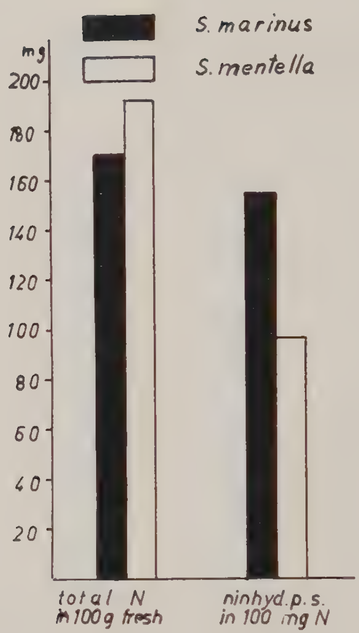

Figure 3. Content of total N and ninhydrin positive substances in redfish types (yearly mean).

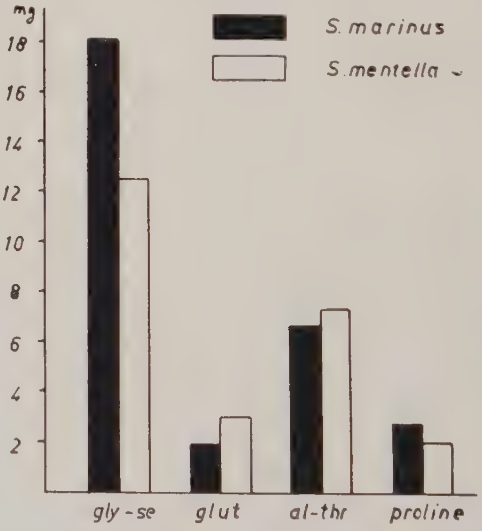

Figure 4. Yearly mean content of free amino acids in redfish types. – gly-se = glycine-serine; glut = glutamic acid; al-thr = alanine-threonine.

acid and alanine-threonine were found in *mentella*, whilst the amount of glycine-serine was nearly the same in both the types.

Figure 7 shows the range of concentration of some free amino acids at station 2305. For glutamic acid and alanine-threonine differences are very considerable, there being no value common to both *marinus* and *mentella*.

At station 2579 (Fig. 8) differences can be seen in the content of glycine-serine and alanine-threonine. The values of glutamic acid and, also, the estimated amounts of proline are little different in the two types. A similar result for glutamic acid is observed in the analysis of the fishes from station 2536 (Fig. 9) but here rather more proline was found in *marinus*.

In reviewing these results it was necessary to analyse statistically (Koller, 1955)* the values obtained. First the applied method sometimes contains considerable errors in determinations; secondly a great biological variability of the single values has been found in some cases; thirdly the number of the fishes dealt with seems to be relatively small. Therefore it must first be proved whether the errors in the analytical determinations are so great that they could come within the range of the biological variability. According to the distribution of F, the variances of the biological variability (s_1^2) are compared with those of the errors of the method (s_2^2). The result is shown in the column s_1^2/s_2^2 of Table 1.

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* The statistical calculations had not been made when the results cited were presented at the ICES/ICNAF Redfish Symposium 1959.

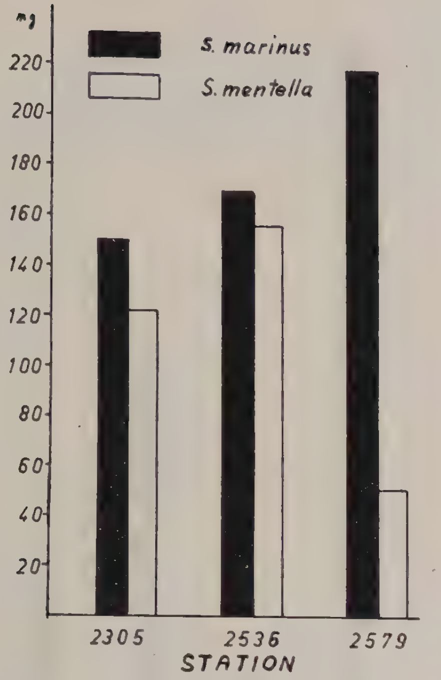

Figure 5. Content of ninhydrin positive substances in redfish types from several stations.

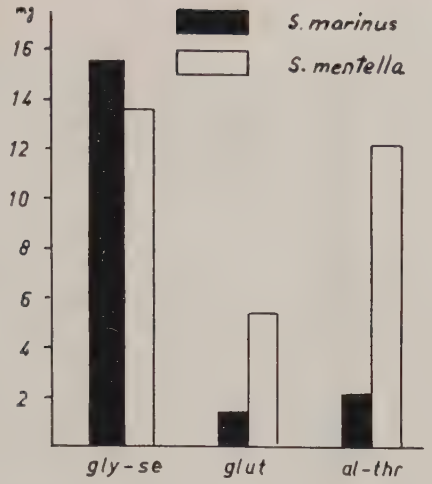

Figure 6. Station 2305, 4. April 1958. Content of free amino acids in redfish types.

The differences between the fishes of each class cannot be attributed only to the errors of the determinations. In nearly all cases the biological variability is significantly higher than the errors at the 0·1 % level, and even at the 5 % level in a few cases.

Next, the differences between *marinus* and *mentella*

Table 1

Comparison of *Sebastes marinus* and *S. mentella* with regard to some substances of the skeletal muscle

		S. marinus				*S. mentella*				t	α
Substance	Season	$\bar{x}$	s	n	s_1^2/s_2^2	$\bar{x}$	s	n	s_1^2/s_2^2		
n.p.s.	winter	156	40·9	14	sig!	92	53·8	7	sig!	3·06	1 % !
	summer	152	49·3	12	sig!	99	60·3	9	sig!	2·27	5 % !
N	winter	158	30·9	26	sig!	191	31·0	8	sig!	2·67	2 % !
	summer	185	46·1	12	sig!	192	13·8	9	sig!	0.5	≒ 30 %
gly-se	winter	15·7	5·39	14	sig!	11·8	3·16	6	sig!	1·62	≒ 20–10 %
	summer	20·5	8·88	12	sig!	12·9	5·19	9	sig!	2·29	5 % !
glut.	winter	1·86	1·52	14	sig!	4·03	2.25	6	$\alpha = 5$ %	2·52	5 % !
	summer	1·91	0·94	12	sig!	1·99	0·88	9	$\alpha = 5$ %	0·2	–
al-thr	winter	5·54	3·83	14	sig!	9·67	4·35	6	$\alpha = 5$ %	2·12	5 % !
	summer	7·72	3·45	12	sig!	5·78	2·37	9	sig!	1·45	≒ 20 %

Abbreviations:

$\bar{x}$ = mean
s = standard deviation
n = number of fishes
t = t from t-distribution
sig! = significant at the 0·1 % level
! = significant at the indicated level
α = level of significance
s_1^2/s_2^2 = comparison of the variances of the biological variability and the errors of determination. F-test

n.p.s. = total ninhydrin positive substances
N = total nitrogen in the muscle extracts, mg in 100 g fresh muscle
gly-se = glycine-serine
al-thr = alanine-threonine
glut. = glutamic acid

The concentrations of n.p.s. and of the amino acids, expressed in mg, are referred to 100 mg total extract nitrogen.

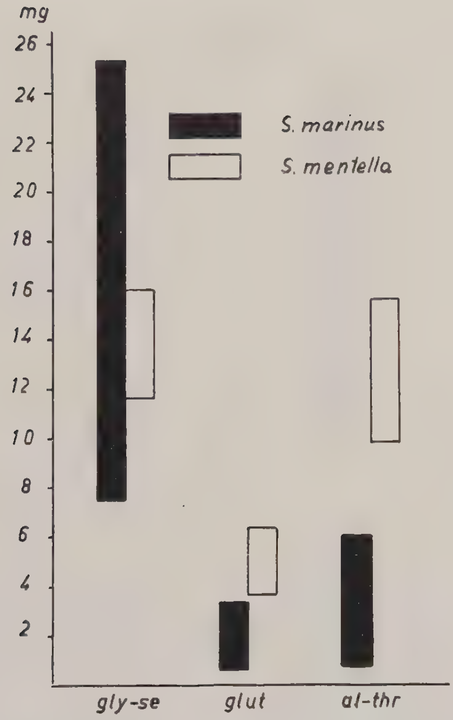

Figure 7. Station 2305, 4. April 1958. Content of free amino acids in redfish types (range of concentrations).

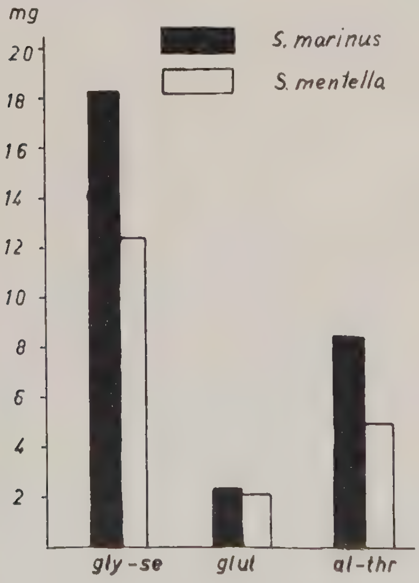

Figure 8. Station 2579. 6. September 1958. Content of free amino acids in redfish types.

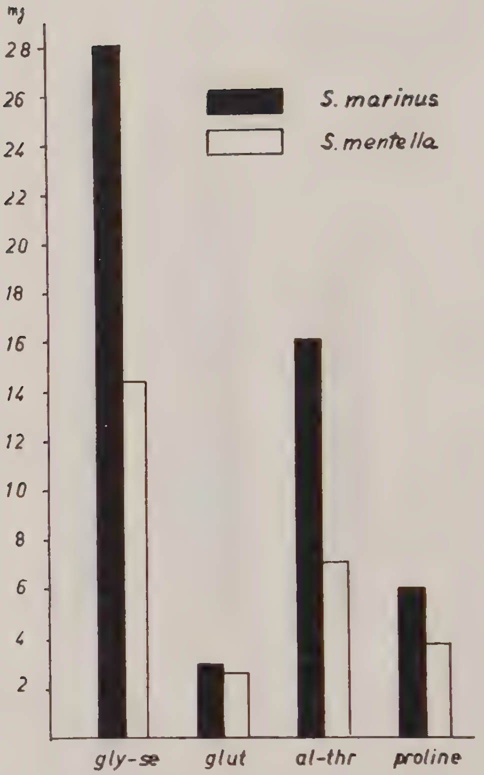

Figure 9. Station 2536, 23. August 1958. Content of free amino acids in redfish types.

are regarded statistically. The two types of fish are separated in summer and winter catches and for each class a common mean value $(\overline{x})$ and standard deviation (s) is stated. This "s" is composed of s_1 of the biological variability and of s_2 caused by the methodical errors according to $s = \sqrt{s_1^2 + \frac{s_2^2}{k}}$. The comparison of the two redfish types is made according to the distribution of t. The results are listed in Table 1.

Whilst only a slight difference is to be seen between *marinus* and *mentella* in Figure 3 in the concentrations of total nitrogen extract, it could be proved statistically that this difference is significant in the winter catches, but not for the samples taken in summer. The great difference in the amounts of the ninhydrin positive substances are confirmed, too.

The divergences demonstrated in Figure 4 are significant at the 5 % level for glycine-serine, glutamic acid, and alanine-threonine.

The comparison of *marinus* and *mentella* by means of the distribution of t confirms that there are biochemical differences between the two redfish types.

These positive results are confirmed if fishes of the two types caught in the same haul are compared. Two examples are given in Table 2. Station 2305: A very high significance is shown for glutamic acid and alanine-threonine. The results given in Figures 6 and 7

Table 2
Comparison of *Sebastes marinus* and *S. mentella* caught at the same stations

(The concentrations of the n.p.s. and of the amino acids expressed in mg referred to 100 mg total extract nitrogen, the concentrations of N in mg referred to 100 g fresh muscle.)

Substance	Type	$\bar{x}$	s	n	t	α
	Station 2305					
n.p.s.	*marinus*	151	65·5	4	0·65	–
	mentella	122	61·0	4		
gly-se	*marinus*	15·4	7·41	4	0·5	–
	mentella	13·5	1·85	4		
glut.	*marinus*	1·3	0·78	4	6·07	0·1 % sig!
	mentella	5·4	1·10	4		
al-thr	*marinus*	2·1	2·2	4	6·3	0·1 % sig!
	mentella	12·2	2·4	4		
N	*marinus*	197	39	4	0·1	–
	mentella	199	31	4		
	Station 2579					
n.p.s.	*marinus*	218	16	2	17·9	0·1 % sig!
	mentella	51	5·4	3		
gly-se	*marinus*	18·2	8·36	2	0·9	–
	mentella	12·4	2·62	3		
glut.	*marinus*	2·2	0·08	2	0·15	–
	mentella	2·1	0·72	3		
al-thr	*marinus*	8·4	1·63	2	1·81	10 -20 %
	mentella	4·9	2·33	3		
N	*marinus*	195	23·1	2	0·15	–
	mentella	197	12·5	3		

Abbreviations: see Table 1.

are thus confirmed. Station 2579: The results obtained from Figure 8 cannot be confirmed. The differences are not significant, though there is a high probability (of about 80–90 %) for alanine-threonine and of about 70 % for glycine-serine. However, at this station the values for the ninhydrin positive substances (Fig. 5) differ between the types by the very high significance of the 0·1 % level.

Table 2 confirms in any way that *marinus* and *mentella* do not present at all homogeneous populations.

The problem as to whether the differences in the free amino acid pools of the skeletal muscle of the redfish types are conditioned genetically or by some other unknown influence cannot be decided by this investigation. Differences due to environment (salinity, oxygen content, temperature) are ruled out, since the biochemical differences were evident at those stations where *marinus* and *mentella* were caught in the same haul. Is it possible that the "spawning" time of *marinus* differs from that of *mentella*?

Investigations of the pattern of free peptides in *marinus* and *mentella* are being carried out.

Summary

Redfish of the types *marinus* and *mentella* have been caught at several fishing grounds in the North Atlantic between Iceland and Greenland during two seasons. By means of two-dimensional paper chromatography alcoholic extracts of the skeletal muscle were analysed for free amino acids.

No qualitative differences in the pattern of these substances were found in the two redfish types.

The concentration of some amino acids was determined by a quantitative paper chromatographic method, using the copper complex of the ninhydrin coloured spots.

The significance of the results is shown by means of statistical methods. It was found that *marinus* and *mentella* differed significantly in the content of certain free amino acids, of the ninhydrin positive substances (which above all are composed of amino acids) and of total nitrogen extract in the muscle tissue.

The divergences were found, too, in *marinus* and *mentella* caught at the same station.

It is thus proved that *marinus* and *mentella* do not present homogeneous populations.

The biochemical analysis confirms and completes the findings hitherto reached by other biological methods.

Acknowledgments

I wish to express my gratitude to the Deutsche Forschungsgemeinschaft for a grant.

The analyses were carried out in the laboratories of the Fischereibiologische Abteilung, Institut für Meereskunde der Universität Kiel. I am greatly indebted to Prof. Dr. Kändler for his kind hospitality and aid.

Finally I owe thanks to Dr. Kotthaus, Biologische Anstalt Helgoland, for several discussions of the redfish problems, and to his assistant Mr. Marschall for his help in determining the redfish types.

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B. 3

Parasitological Tags for Redfish of the Western North Atlantic

By
CARL J. SINDERMANN
U. S. Bureau of Commercial Fisheries, Boothbay Harbor, Maine

Introduction

Parasites and diseases of animals may vary in abundance geographically, so that individuals sampled in one area may be recognized by certain frequencies of particular parasites, or even by parasites that are not found in another area. If we can characterize marine fish in this way, by assessing parasite frequencies on each fishing ground, or in spawning aggregations, it should be possible to determine the nature and extent of movements, if any. This method has already been applied with some success to sea herring of the western North Atlantic, which have been found to participate in only local movements (Sindermann, 1957a; 1957b). Some information has also been gained about redfish (*Sebastes marinus*) stocks of the western North Atlantic by studying the distribution of a single parasite, the copepod *Sphyrion lumpi* (Herrington, 1939; Templeman, 1950; Knapp-Fisher, 1952; Perlmutter, 1953). Lüling (1951) noted that redfish from different grounds off Iceland varied widely in incidence of larval nematodes (Anisakinae). Since redfish from deep water are difficult to tag, a detailed study of parasites as "natural marks" may be a method of choice in population and migration studies.

Since the discontinuous distribution of *Sphyrion* in redfish of the western North Atlantic had already indicated lack of extensive movements of host fish, it seemed that by examination of the distribution of other redfish parasites, it might be possible to determine the precise amount of interchange, if any, among the major fishing grounds. Although much more intensive sampling over a long period is needed, results to date have been informative and are presented in this report.

Methods

Redfish samples of 100 fish each were obtained from otter trawlers unloading at Rockland, Maine, and Gloucester, Massachusetts. Figure 1 shows locations of major fishing grounds sampled. Only fish of commercial size were examined, so individuals below the minimum size for filleting (approximately 15 cm) were not included. Some selection for size was also imposed by the nature of the catches, since some were composed principally of smaller fish (as in Grand Banks samples) and others were composed principally of larger fish (especially Cape Cod Highlands and Gulf of Saint Lawrence samples). Although not determined in the present study, the age of the fish may affect its parasite burden. This is a factor that should be investigated in any future large-scale parasite sampling programme.

When possible, several samples taken during different months were obtained from each area. Fish were examined individually for the following parasites:–

1. *Sphyrion lumpi* – an ectoparasitic copepod with its anterior end permanently embedded in the body of the host;
2. *Chondracanthopsis nodosus* – an ectoparasitic copepod attached to the basal portions of the gills;
3. *Ichthyosporidium hoferi* – a systemic fungus parasite which produces white nodules on and in the heart, spleen, and liver;
4. Trypanorhyncha – larval cestodes encysted in the stomach wall and adjacent mesenteries; and
5. Anisakinae – larval nematodes, encysted or migratory, in the viscera.

The parasite fauna of redfish is much larger than this, but the parasites listed were selected because they could be recognized readily, because they seemed to be relatively permanent, and because in preliminary work they were found to vary in abundance geographically. All parasites were preserved for subsequent identification, and incidence of each species was recorded for each major fishing area.

Results

Photographs of certain parasites considered in this study as "natural tags" are included in Figure 2. Average incidence in each major fishing area is summarized in Table 1, and data from each sample are included in Table 2.

The data illustrate the often dramatic differences in abundance of certain parasites on different fishing grounds. In some cases such as *Sphyrion*, Trypanorhyncha, and *Ichthyosporidium* the parasite was absent from samples taken in certain areas, but was abundant in other areas. There was no evidence that the

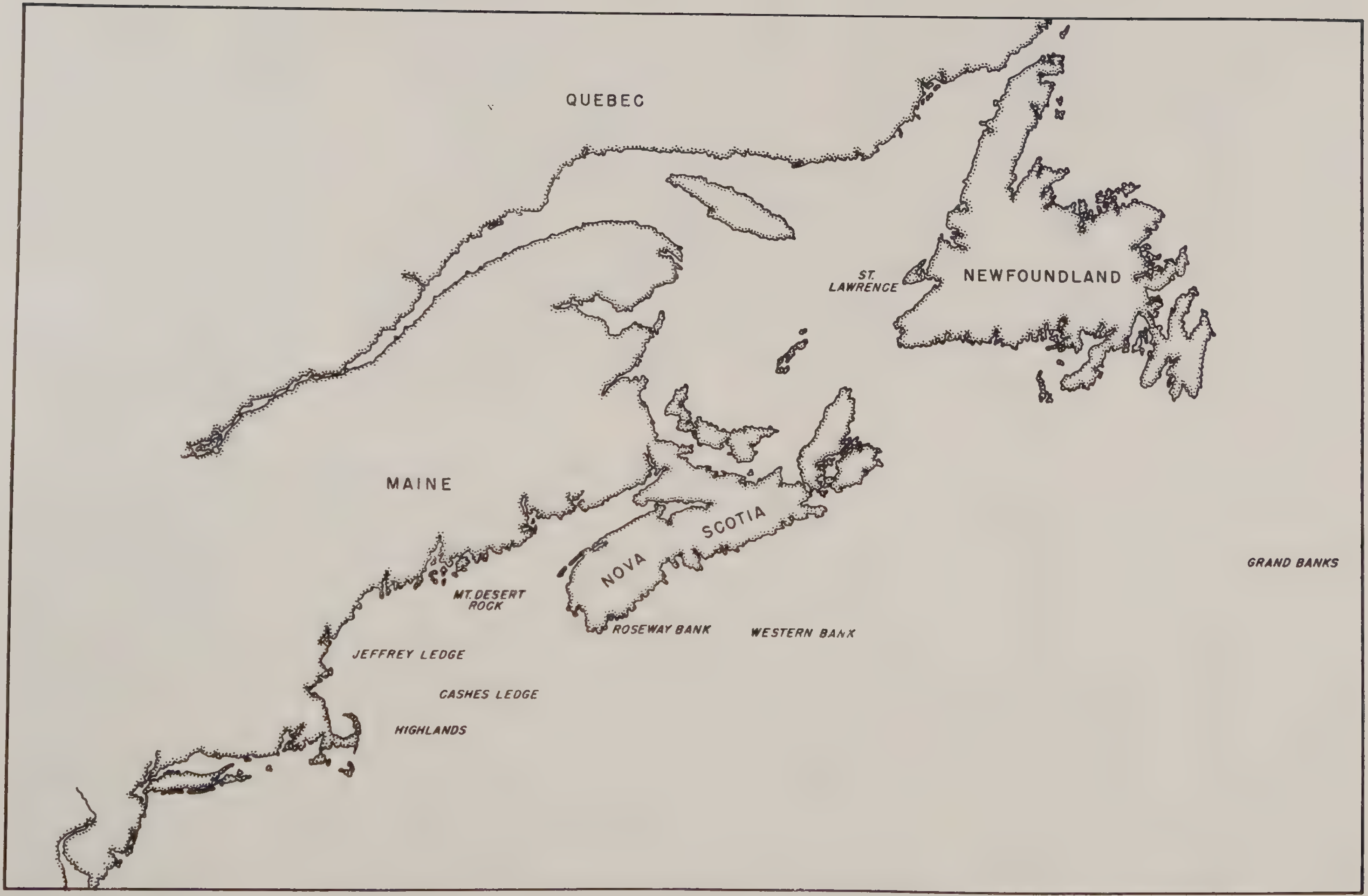
QUEBEC
ST. LAWRENCE
NEWFOUNDLAND
MAINE
NOVA SCOTIA
GRAND BANKS
MT. DESERT ROCK
ROSEWAY BANK
WESTERN BANK
JEFFREY LEDGE
CASHES LEDGE
HIGHLANDS

Figure 1. Locations of major fishing grounds sampled in the present study.

Table 1
Parasite incidences in redfish of the western North Atlantic

Fishing Ground	Parasite Incidences (%)				
	Sphyrion lumpi	*Chondracanthopsis nodosus*	*Ichthyosporidium hoferi*	Trypanorhyncha	Anisakinae
Grand Banks	0	14	1	0	7
Western Bank	0	46	5	25	10
Roseway Bank	0	25	0	22	69
Mount Desert Rock	24	23	0	50	56
Jeffrey Ledge	0	8	0	46	68
Cashes Ledge	14	13	0	26	31
Cape Cod Highlands	9	6	0	14	45
Gulf of Saint Lawrence	0	2	1	0	21

Table 2
Results of parasite examination of redfish

Fishing ground	Dated sample (1959)	Parasite Incidences (%)				
		Sphyrion lumpi	*Chondracanthopsis nodosus*	*Ichthyosporidium hoferi*	Trypanorhyncha	Anisakinae
Grand Banks	Jan.	0	15	1	0	8
	Mar.	0	12	0	0	6
Western Bank	Jan.	0	45	6	–	10
	Jan.	0	48	3	25	–
Roseway Bank	May	0	25	0	22	69
Mount Desert Rock	Jan.	25	21	0	50	56
	Jan.	22	26	0	–	–
Jeffrey Ledge	Jan.	0	8	0	46	68
Cashes Ledge	Mar.	14	13	0	26	31
Cape Cod Highlands	Mar.	9	6	0	14	45
Gulf of Saint Lawrence	July	0	1	1	0	21
	Aug.	0	–	0	0	–
	Aug.	0	4	0	0	–

abundance of one parasite was in any way influenced by another, although factors such as temperature, depth, presence of intermediate hosts, and proximity to shore may have had an effect. There was no definite evidence for seasonal variation in frequency of parasites, although more extensive sampling might modify this finding.

Sphyrion lumpi was found only on fish from the Gulf of Maine, with a peak abundance in the Mount Desert Rock samples. More detailed studies of the distribution of this copepod in the Gulf of Maine have been made previously (Herrington, 1939; Perlmutter, 1953; Kelly, 1957) and incidences reported here agree well with published data. Greater numbers of samples might disclose very low incidences of this and other parasites in certain areas listed as negative. This proved to be the case in extensive sampling for *Sphyrion* reported by Templeman (1950) and Knapp-Fisher (1952).

The gill copepod, *Chondracanthopsis nodosus,* reached a peak of abundance in samples from Western Bank, and decreased in the southern Gulf of Maine, while larval nematodes (Anisakinae) were least abundant on the offshore banks. Larval cestodes (Trypanorhyncha) were absent in Grand Banks and Gulf of Saint Lawrence samples, and were most abundant in the northern Gulf of Maine. *Ichthyosporidium hoferi,* the fungus parasite, was absent from Gulf of Maine samples, and was found only in fish from Western and Grand Banks and the Gulf of Saint Lawrence.

Discussion

It should be possible with data such as these to determine with some precision the maximum possible interchange of redfish between any two fishing grounds. This method considers parasites and parasite frequencies as characteristics of stocks in any particular area, and is based on the following assumptions:–

(1) that the parasite is relatively permanent – persisting for at least several years;

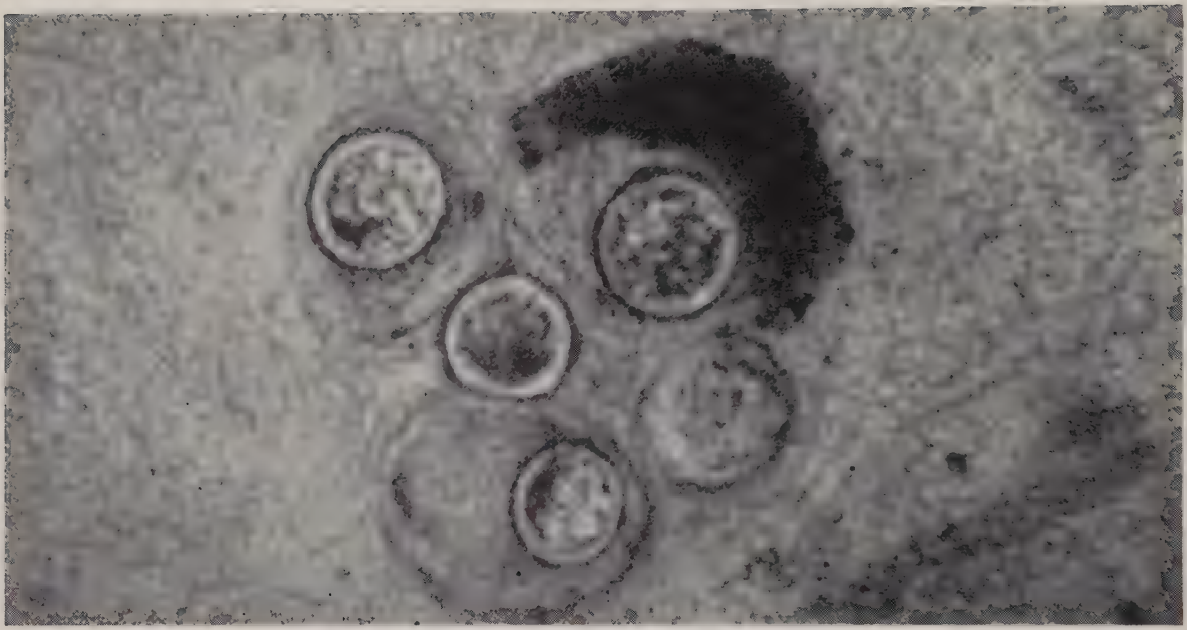

Figure 2. Parasites used as "natural tags" for redfish.

(a) Photomicrograph of spores of the fungus *Ichthyosporidium hoferi* in a redfish heart. Spores range in diameter from 30–60 microns, are characteristically multinucleate with a heavy spore wall, and are encapsulated by host connective tissue. The parasite produces white nodules on heart, liver and spleen.

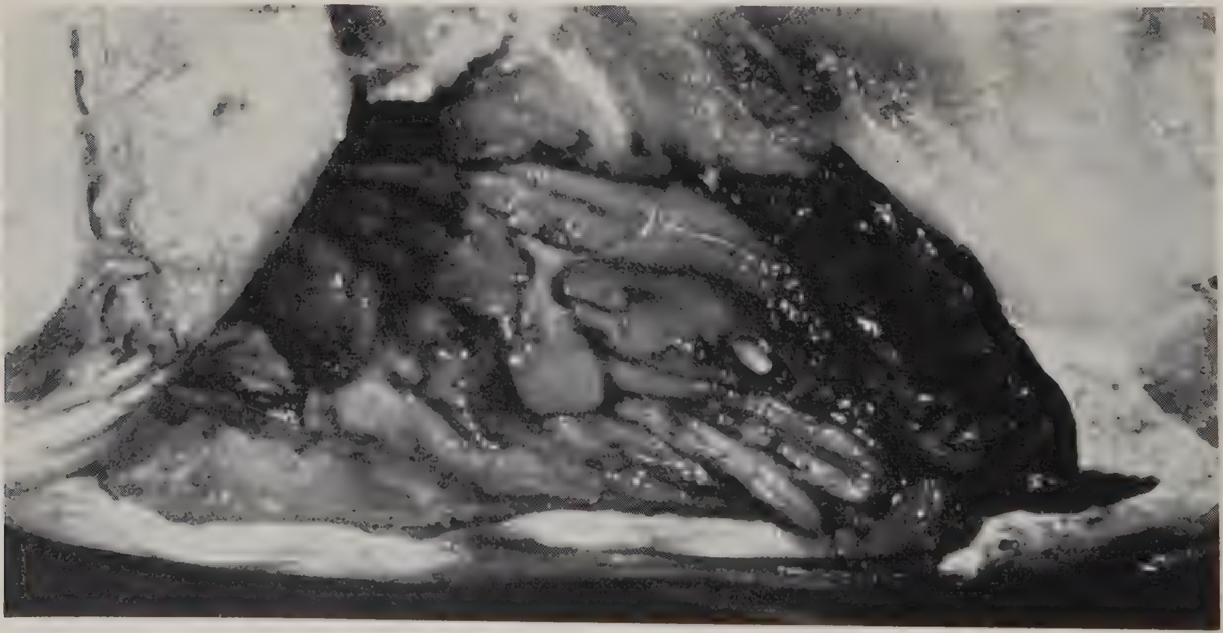

Figure 2 (b). A larval cestode (Trypanorhyncha) encysted in the mesenteries of a redfish.

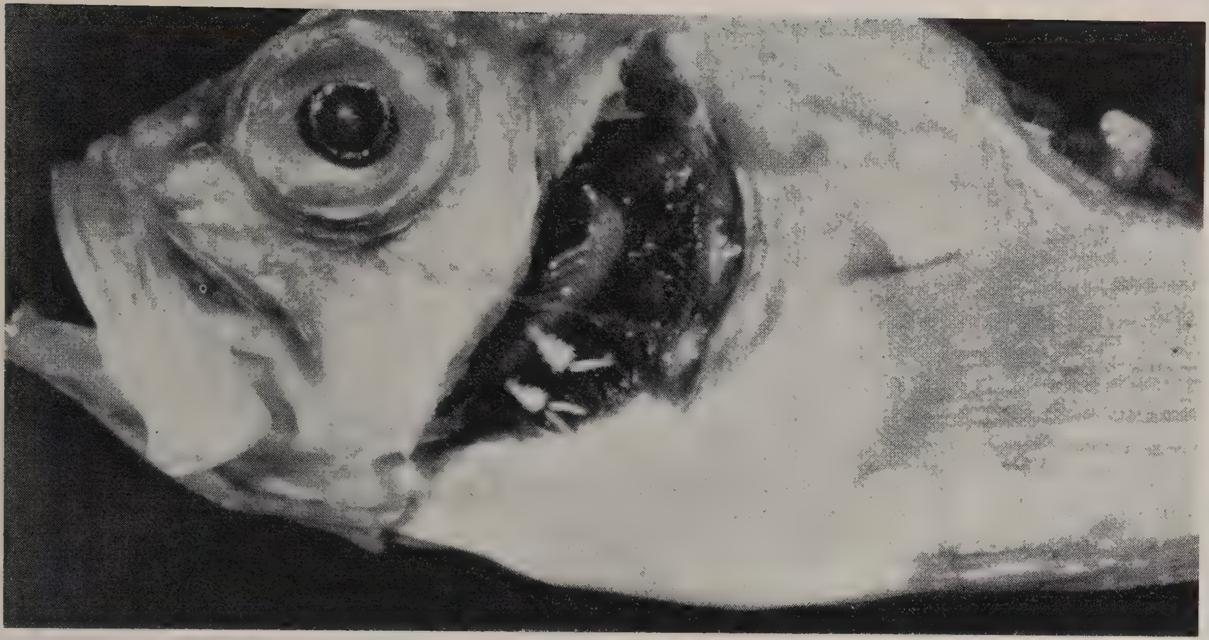

Figure 2 (c). Parasitic copepods (*Chondracanthopsis nodosus*) on the exposed gills of a redfish.

(2) that the parasite will not kill its host; and

(3) that incidences of particular parasites in an area will remain relatively stable for several years, or at least will not fluctuate widely from one year to the next.

Experimental and ecological studies therefore should be a part of any attempt to use parasitological tags, in order to be certain that the above criteria are fulfilled by each parasite studied.

In some cases the absence of a parasite in an area gives a strong indication of the extent of possible intermixing of fish from adjacent areas. For example, in our data, larval cestodes (Trypanorhyncha) were absent from Grand Banks and Gulf of St. Lawrence redfish samples, but were abundant in all other areas. This discontinuity could only be maintained by lack of any effective movement of fish from areas where the parasite occurs to the Grand Banks or the Gulf of St. Lawrence. Also, the localization of the copepod *Sphyrion* in the Gulf of Maine and its virtual absence in adjacent areas preclude any extensive movement of redfish so parasitized out of the Gulf.

Usually, however, the situation is not so definitive. Most parasites occur throughout the host range, but in widely varying abundance. In this situation determination of average incidences in each area for several parasites can provide a maximum estimate of intermixing. For example, redfish from Western Bank have almost twice as many gill copepods as fish from the adjacent Roseway Bank, but only one-seventh the numbers of larval nematodes. This suggests that maximum possible interchange between these two areas is slight, otherwise greater homogeneity would exist. It is, therefore, the *composite* of frequencies of several parasites that characterizes fish from a geographic area and that may be compared with composites from other areas to obtain an indication of maximum possible intermixing. For example, comparing parasite incidences in Roseway, Western, and Grand Banks samples (Figure 3) the maximum possible interchange could be determined mathematically.

Parasite frequencies, then, can provide a means of estimating or calculating maximum *possible* movement, but the *actual* movement may be much less. As is true of most methods for the study of marine fishes, a parasitological study by itself would rarely produce definitive answers to population and migration problems. However, when parasitological data are combined with information derived from other methods of study, a significant contribution may be made.

Conclusions

(1) A survey has been made of the frequencies of five redfish parasites from the western North Atlantic. Parasites were selected for use as "natural tags" because they were relatively permanent, easily visible, and varied in abundance on different fishing grounds.

(2) Fish from each of the major fishing grounds

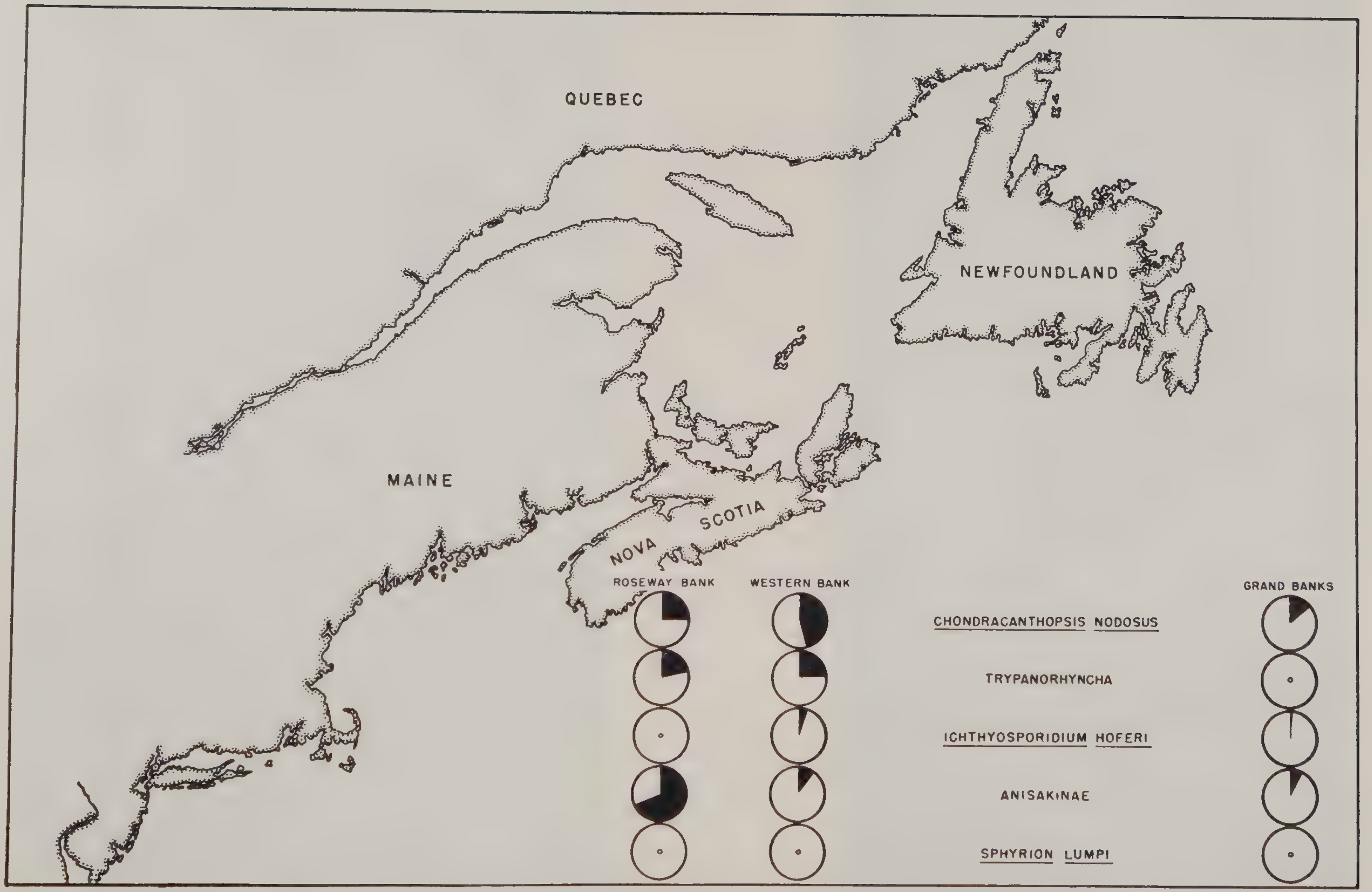
QUEBEC
NEWFOUNDLAND
MAINE
NOVA SCOTIA
ROSEWAY BANK
WESTERN BANK
GRAND BANKS
CHONDRACANTHOPSIS NODOSUS
TRYPANORHYNCHA
ICHTHYOSPORIDIUM HOFERI
ANISAKINAE
SPHYRION LUMPI

Figure 3. Incidences of five parasite tags in redfish samples from Roseway, Western, and Grand Banks.

were characterized by a composite of frequencies of all parasites. Samples from each area were distinguishable parasitologically from those of any other area.

(3) The discontinuous distribution of a larval cestode indicated that Grand Banks redfish stocks receive no contribution of adults from stocks to the westward. Localization of an ectoparasitic copepod in the Gulf of Maine indicated that the fish populations on more eastern grounds receive no contribution from the Gulf of Maine.

(4) Composite parasite frequencies of adjacent redfish stocks in and near the Gulf of Maine suggest that maximum possible intermixing is slight, even for those stocks not widely separated geographically.

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B. 4

Serological Studies of Redfish[1]

By

CARL J. SINDERMANN
U. S. Bureau of Commercial Fisheries, Boothbay Harbor, Maine

Abstract

During the past decade there has been increasing interest in the use of serology for systematic studies of fish. Of the varied techniques available to serology, investigation of erythrocyte antigens, and subsequent description of blood group systems containing them, offer greatest promise to the understanding of infraspecies groups. Quantitative study of antigen frequencies in fish from different geographic areas may provide information about the degree of intermixing and movement of populations within a species.

As the first phase in such a programme for redfish, *Sebastes marinus,* from the North Atlantic, individual variations in cellular antigens have been examined. The existence of two closely related antigens, tentatively labelled "A_1" and "A_2", has been demonstrated with specific reagents created by absorptions of rabbit antisera. Each reagent would agglutinate cells of only one antigenic type, so it was possible to identify fish as possessing A_1 or A_2 antigen. Although much more extensive sampling is needed, it has been found that individuals with the A_2 erythrocyte antigen make up less than 10 % of the Eastport (Maine) redfish population. Since antigen frequencies may vary from one population to another, quantitative studies of each major fishing area should provide further information about discreteness of the groups involved.

In addition to quantitative studies of A antigen frequencies, search should be made for other antigens and systems in redfish, to enable more precise characterization of each population. Serology can then constitute an important criterion, along with traditional morphometric and meristic studies, for understanding the infraspecies structure of redfish.

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[1] The complete paper in Fish. Bull. U.S. Fish & Wildl. Serv., *61.*

B. 5

Incidence and Distribution of Infestation by *Sphyrion lumpi* (Krøyer) on the Redfish, *Sebastes marinus* (L.) of the Western North Atlantic, 1949-1953[1]

By

WILFRED TEMPLEMAN and H. J. SQUIRES
Fisheries Research Board of Canada Biological Station, St. John's, Newfoundland

Abstract

Investigation of the infestation of redfish by female *Sphyrion lumpi,* in the Newfoundland area, showed that in the Labrador area the parasites were generally distributed all over the body, but that the greatest infestation occurred in the cloacal region. In the eastern Grand Bank area there was a strongly ventral distribution of the parasite on the trunk, with over 40 % in the cloacal area. This is contrasted with previously published data from the Gulf of Maine, where most of the *Sphyrion* were situated antero-dorsally, near the base of the spiny first dorsal fin.

In the Newfoundland area, the major geographical centre of infestation was off southern Labrador, east of Hamilton Inlet Bank, where up to 8 % of the redfish were infested. Centres of lower levels of infestation were found on the southern part of the eastern slope of the Grand Bank and in the south-eastern part of the Gulf of St. Lawrence. *Sphyrion* were very scarce on the south-western Grand Bank, the western part of the south coast of Newfoundland, and in the northern part of the Gulf of St. Lawrence. They were not noted on redfish from the north-eastern Grand Bank, Flemish Cap, and from the Nova Scotian Shelf.

A study of cephalothorax remains in redfish fillets showed the same geographical centres of abundance as derived from live parasite counts, but there was some evidence of a spread of previously infested fish moving into some other areas. The data suggest a slow migration in the direction of a deep water current.

It is believed that almost all the redfish discussed in the paper were of the *mentella* type.

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[1] Complete paper in J. Fish. Res. Bd. Canada, *17* (1): 9–31, 1960.

SECTION II

REDFISH DISTRIBUTION

Discussion Leader: Dr. W. TEMPLEMAN

The following papers were presented and discussed:–

Bergeron, J. "Redfish explorations in the Gulf of St. Lawrence, 1957".

Dietrich, G., Aurich, H., & Kotthaus, A. "On the relationship between the distribution of redfish and redfish larvae and the hydrographical conditions in the Irminger Sea".

Freund, K. "Some observations on the redfish of the Labrador region".

Jean, Y., & McCracken, F. D. "Incidental catches of redfish in cod and haddock surveys off the southern Canadian Mainland during the years 1957 to 1959".

Martin, W. R. "The distribution of redfish catches landed on the southern Canadian Mainland, 1949–1958".

Templeman, W. "Redfish distribution in the North Atlantic". (Abstract from Bull. Fish. Res. Bd. Canada, No. 120. 1959.)

Templeman, W. "Redfish distribution off Baffin Island, northern Labrador, and in Ungava Bay in August–September 1959".

1. Species discussed

The papers presented were mainly concerned with both types of *Sebastes marinus* and to a minor degree, only, with *Sebastes viviparus*.

2. Redfish landings

The total landings of redfish from the ICNAF area in 1957 were 159,000 metric tons and in 1958 the catch rose sharply to 315,000 metric tons. The total redfish landings in 1957 from the remainder of the North Atlantic, the part of the ICES area from East Greenland to the Barents Sea were 233,000 metric tons. In recent years many virgin redfish populations have been discovered, but usually the catch per unit effort has quickly decreased in each of these newly fished areas.

3. Depth distribution of *Sebastes viviparus*

New verbal information was brought forward showing that individuals of *Sebastes viviparus* extend as deeply as those of other redfish species.

4. Relationship of *marinus* and *mentella* forms of redfish to depth and temperature

Although individuals may be found at all redfish depths, populations of the *marinus* type usually live at lesser depths than those of the *mentella* type. In the northern and eastern Labrador and Newfoundland bank and shelf areas where the overhead layer of cold Labrador Current water is deeper, both *marinus* and *mentella* live more deeply than in the western and southern parts of the Canadian area where this overlying cold layer is thinner, but in each case the relative depth levels of *marinus* and *mentella* remain approximately the same.

In the North-East Atlantic the *marinus* type lives in the upper warmer layer of North Atlantic Current water whereas the *mentella* type lives in North Atlantic Current or mixed water of lower temperatures below. In the North-West Atlantic, on the other hand, the *mentella* type lives in the warmer water below, whereas the shallower *marinus* type lives in lower temperatures nearer the overlaying cold layer. At Flemish Cap both types live in water of the same temperature. Since in all these cases the main concentration of the *marinus* type is above and that of the *mentella* type is below, within the redfish usual temperature range of about 3–8°C the depth adaptation and not the temperature is the most important factor in determining the relative vertical distribution of the *marinus* and the *mentella* types.

Marinus-type redfish appear to be much more plentiful in waters of the North-East and North Central Atlantic where they have abundant living space, with suitable temperatures in their main depth range, in the thick upper layer of North Atlantic Current water. *Marinus*-type redfish are relatively scarce in the North-West Atlantic where in the whole area where *marinus*-type fish exist, these fish, accustomed to a shallower depth range than the *mentella* type, have little living space of suitable temperature available to them.

Considerable evidence was brought forward to show that large redfish populations were only to be found in or near areas where temperatures of approximately

3–8°C (in the North-West Atlantic usually 3–6°C) were present in the normal redfish depths. In the vicinity of such areas with suitable temperatures, good catches of redfish may often be made at temperatures as much as several degrees lower than are found in the above depth range.

5. Pelagic populations

Temperature conditions at redfish depths adjacent to the northern redfish areas are suitable for the existence of pelagic populations of redfish. There is, however, very little evidence at present that large pelagic populations exist in these areas. In the southern part of the redfish range in the North-West Atlantic temperatures, at redfish depths, are too high for large pelagic populations to be expected.

6. Factors producing redfish concentrations

Many factors may help to produce local concentrations of redfish. Among these are light, food, spawning cycle, temperature, bank slopes and ridges, depressions in the continental shelf, stranding by currents, V-shaped areas, projections or valleys at the edges of banks, and type of bottom. The considerable value of detailed topographical bottom surveys such as that presented by Dr. Dietrich for the East Greenland area was appreciated by the group, and it was apparent that such detailed surveys are very important as an assistance to fishing and in understanding the redfish distribution.

7. Northern distribution of redfish on the Canadian side of the Labrador Sea

On the Canadian side of the Labrador Sea off Baffin Island and Labrador it is unlikely that large commercial concentrations of redfish occur between latitudes 67° and 58°N and it is evident that the redfish which do exist from latitude 67°N at least as far south as latitude 60°N are almost entirely *mentella*-type redfish which had their origin in larvae coming from West Greenland.

8. Future work on redfish distribution

(a) More detailed information is needed over the whole redfish area of the North Atlantic for *Sebastes viviparus, Sebastes marinus marinus,* and *Sebastes marinus mentella,* on distribution of each form by depth, temperature, numbers, weight, sex and size. This information is required not only for research vessel catches but also for commercial landings.

S. viviparus is apparently readily separable now under field conditions and in any case is not usually a commercial species. To facilitate field separation of other types every effort should be made to find and describe adequately characters which can quickly be used in the same way by all workers to separate the *marinus* and *mentella* types under field conditions. The parameters of normal variation in these two types should be studied with the object of finding field characters to assign as many as possible of the redfish presently called intermediates to one or other of the present types. The problem of whether European and American types of adult *marinus* and of *mentella* can be separated, although an interesting scientific problem, is not of immediate practical importance compared with that of separating adequately by rapid field identification the *marinus*- and *mentella*-type fish within each of these two areas.

(b) Bottom topography appears to have a very important bearing on the distribution and abundance of redfish and indeed of all groundfish, and more effort should be devoted to this subject.

(c) Although considerable data are available in most areas with regard to temperature and salinity, the knowledge of currents, particularly in depths where redfish live, is inadequate for many areas. Efforts to produce this information and to study the effects of the deeper currents on the concentration and dispersal and movement of redfish populations should be considerably increased.

(d) Efforts should be made to investigate the question of the existence of pelagic populations of redfish over the deep water of the North Atlantic.

1.

Redfish Explorations in the Gulf of St. Lawrence, 1957

By
JULIEN BERGERON
Station de Biologie Marine, Grande-Rivière, Quebec

In recent years the economic importance of the redfish (*Sebastes marinus* L.) in the Gulf of St. Lawrence has increased greatly. It was already known that the commercial catches were made only in the deep-water channels of over 100 fathoms of the St. Lawrence.

During summer 1957, the Station de Biologie Marine of Grande-Rivière, Quebec, carried out a survey in a previously unexplored area of the Laurentian Channel south of Anticosti Island.

The fishing was carried on with the 58 foot dragger M.V. "Astrid", belonging to the Quebec Department of Fisheries. Three fishing trips were made in July, August, and September and 33 stations were fished (see the map, Fig. 1.).

On average 2-hour tows were made with a 3/4 style No. 35 Yankee otter trawl having a 39-foot headrope and a 50-foot footrope, and 400 pounds otter boards. The average distance towed per drag was about 4

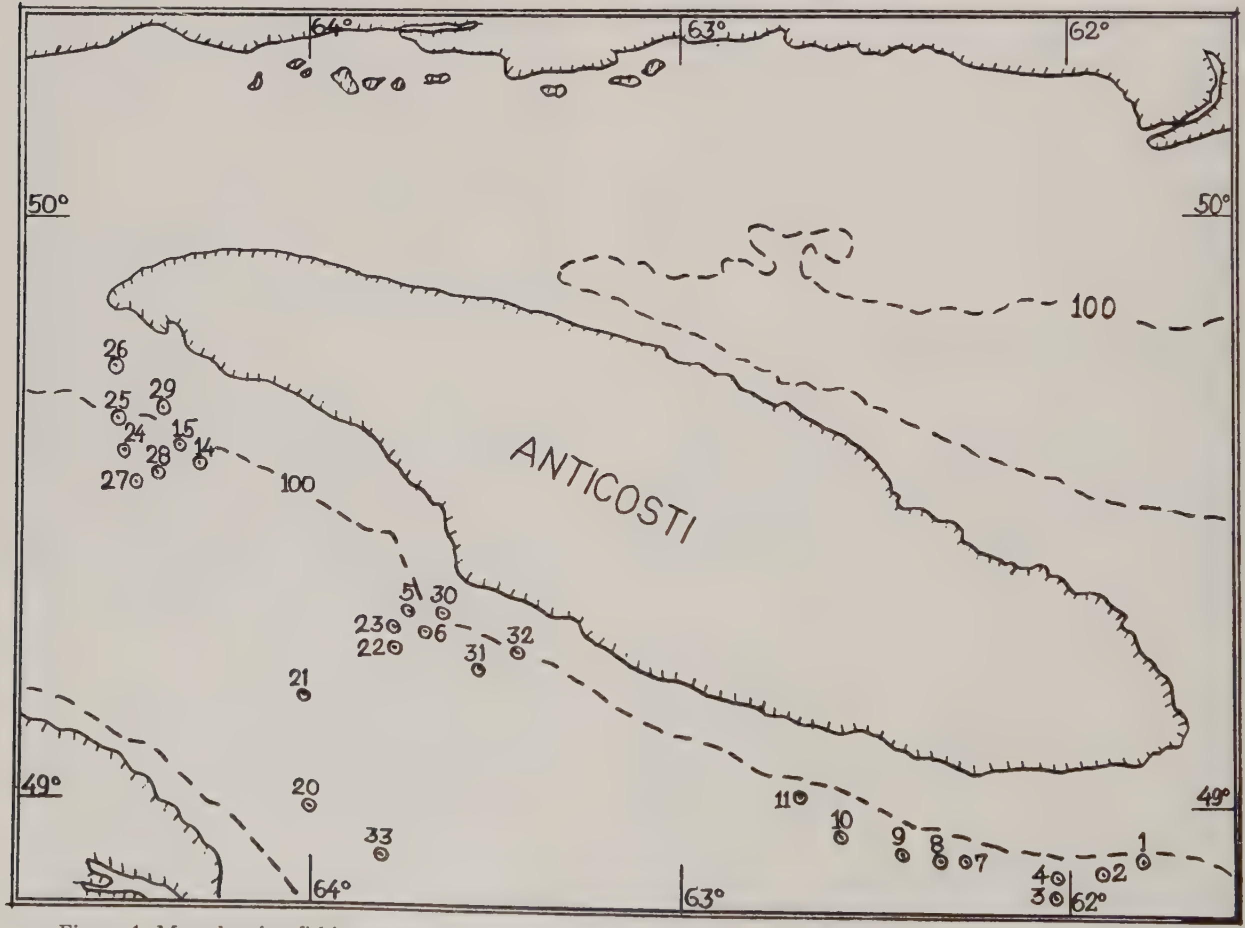

Figure 1. Map showing fishing stations of redfish in the Laurentian Channel, July, August, and September 1957.

Table 1
List of trawling stations and yield of redfish per hour

No. of station[1]	Depth (fm)	Catch (lb per hour)
1	148	649
2	148	686
3	148	434
4	151	882
5	150	1,325
6	140	1,183
7	140	–
8	144	400
9	142	615
10	142	820
11	128	984
14	130	353
15	140	369
20	145	574
21	200	40
22	170	75
23	150	128
24	150	2,000
25	120	–
26	30	–
27	160	375
28	140	1,200
29	90	–
30	128	1,157
31	140	305
32	100	–
33	125	965

[1] These numbers refer to the position on the map.

nautical miles. Depths between 90 and 150 fathoms were surveyed.

Redfish were absent in the 90 and 100 fathoms depth but abundant from 120 fathoms down to 150 fathoms. The best catches were taken along the 145–150 fathom line. All hauls were made in daylight.

Water temperatures near bottom ranged from 38°F (3·3°C) in 100 fathoms, where no redfish were caught, to 42°F (5·6°C) at 150 fathoms, where catches were good (see Table 1). Two random samples were taken at one month interval in the same region and total length measurements were made. In July, the size range for males was 21 to 40 cm and 25 to 45 cm for the females, with a sex ratio (M/F) of 1 : 1·23. In August the size range was 22 to 45 cm for the males and 32 to 48 cm for the females, with a sex ratio (M/F) of 2·09 : 1 (Fig. 2).

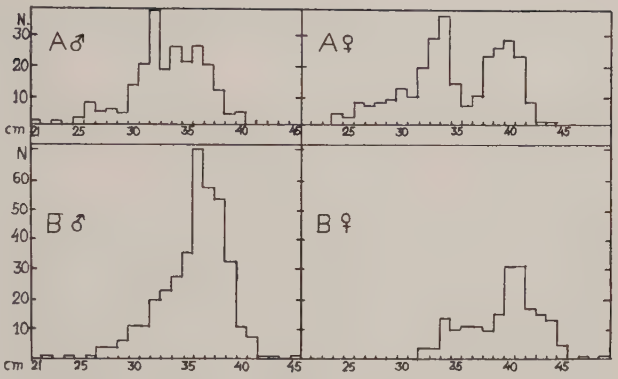

Figure 2. Redfish. Length distribution of males and females in two samples:–
A – 10. July 1957; 219 males and 271 females.
B – 20. August 1957; 384 males and 183 females.

Neglecting the very small proportion of the fish less than 25 cm (10 inches), the catches were indicative of excellent suitability for commercial fishing in the 150 fathoms range.

The bottom in the area deepens gently and is smooth. No serious damage to the net was encountered in 33 drags.

2.

On the Relationship between the Distribution of Redfish and Redfish Larvae and the Hydrographical Conditions in the Irminger Sea

By
G. DIETRICH
Institut für Meereskunde, Kiel
and
H. AURICH and A. KOTTHAUS
Biologische Anstalt Helgoland

Those who have been concerned with the relationship between fish and environment know how difficult it is to arrive at exact statements.

One statement may apply to special circumstances and may then serve as tactical information for fishermen – for example – those which have been compiled for herring, codfish and tuna (G. Dietrich, D. Sahrhage, K. Schubert, 1959). In other circumstances only conjecture about the relationship between fish and environment can be put forward. Finally, in most cases, little can be stated with certainty, and the few facts available are of such a general nature that they are useless as strategic and tactical information for the fishermen. It is thought that the knowledge available for the redfish has, so far, not passed beyond this lowest level. Because of this situation, the three authors dis-

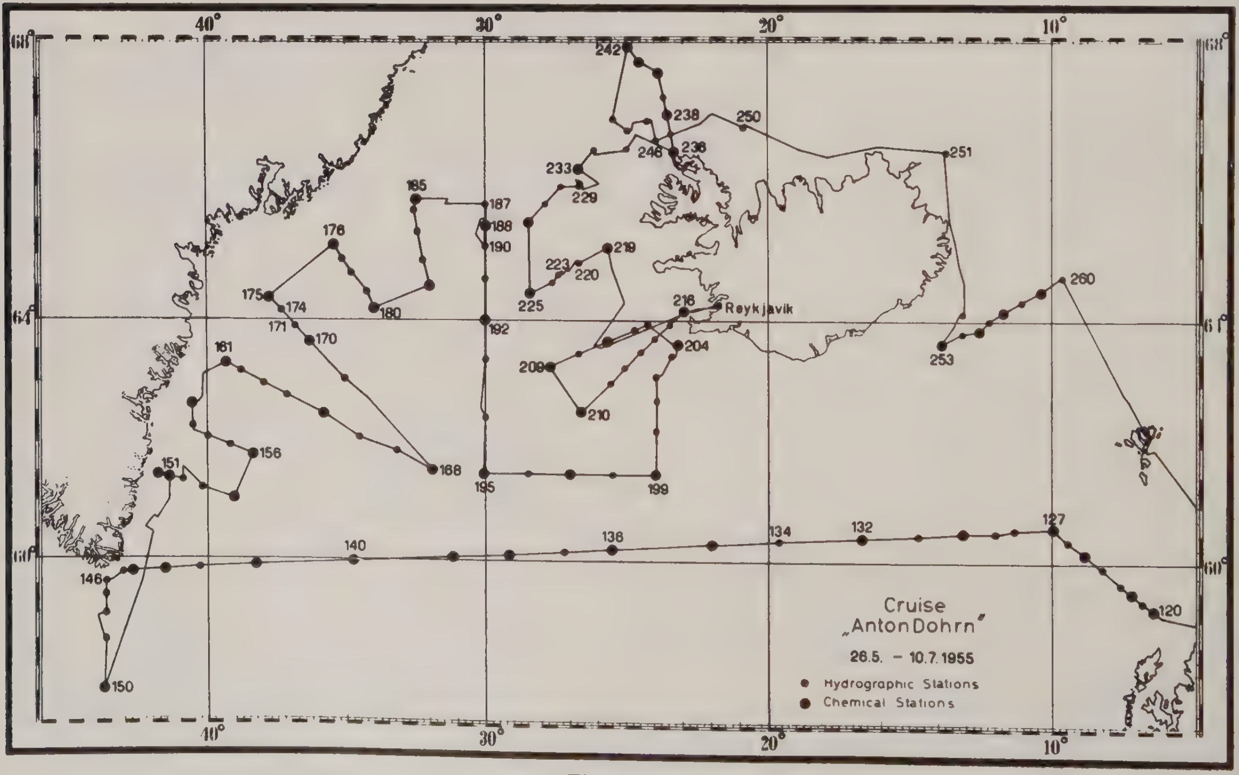
40°
30°
20°
10°
68°
64°
60°
242
238
250
236
246
251
233
229
185
187
188
190
176
219
223
220
175
174
180
225
218
Reykjavik
260
171
170
192
204
161
208
210
253
151
156
168
195
199
140
138
134
132
127
146
120
150
Cruise
„Anton Dohrn"
26.5. – 10.7.1955
● Hydrographic Stations
● Chemical Stations

Figure 1.

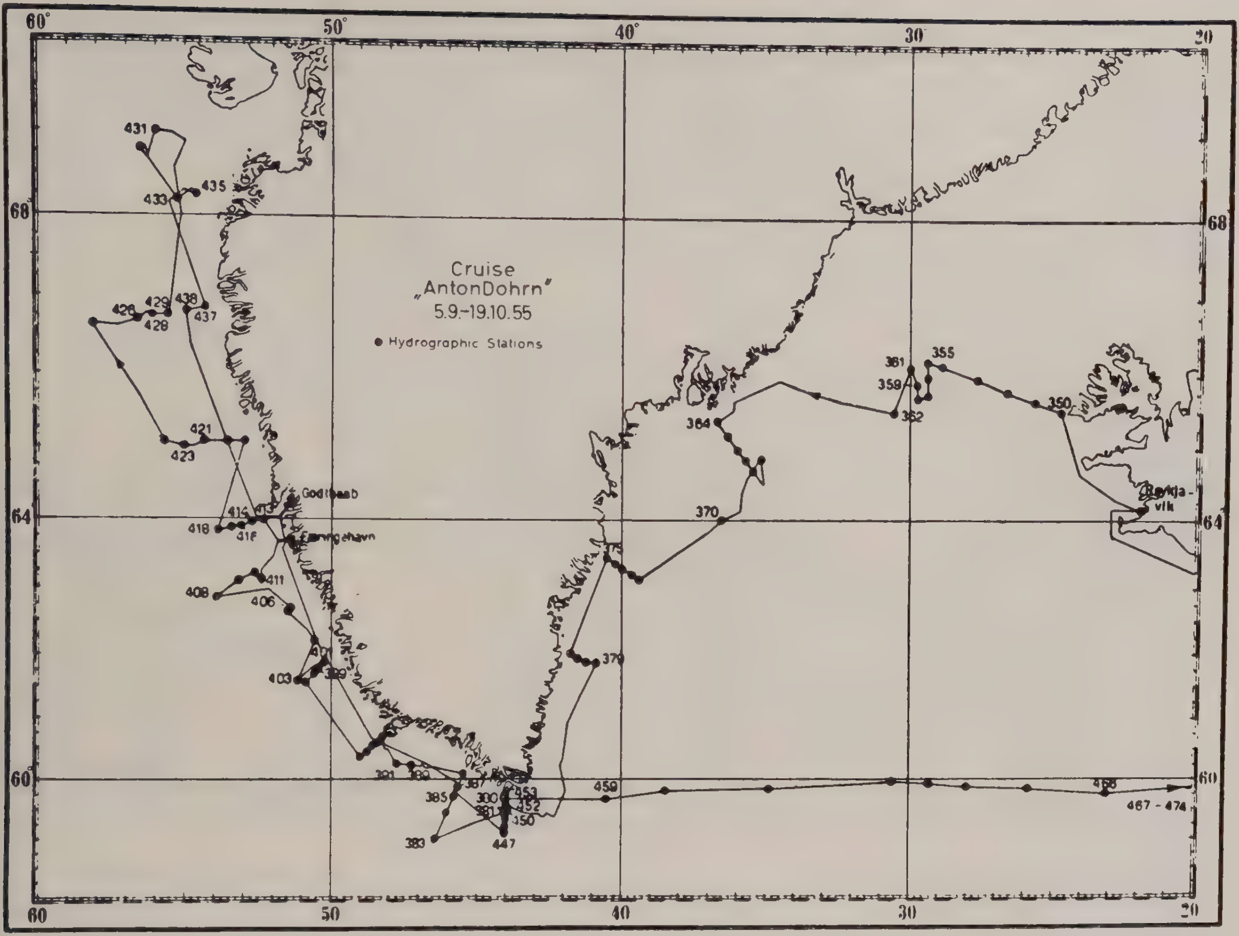
Cruise
„AntonDohrn"
5.9.-19.10.55
● Hydrographic Stations
Godthaab
Færingehavn
Reykja-
vik
60°
50°
40°
30°
20
68
64
60
431
433
435
426
429
428
438
437
421
423
415
418
411
408
406
403
399
391
389
387
385
383
390
381
453
452
450
447
459
458
467 - 474
379
375
370
364
361
359
362
355
350

Figure 2.

cussed their results, based partly on the same cruises, to investigate the relationships between the redfish and redfish larvae and the hydrographical conditions, especially in the waters between Iceland and Greenland.

1. The cruises

On the whole, seven research cruises are considered.

1. In June 1955, the "Anton Dohrn" made a cruise in order to study hydrography and the biology of fish (Fig. 1). It was her maiden trip, on which the three authors, with other scientists, worked extensively on different physical, chemical and planktological problems, as well as on problems concerning the biology of fish. Below follow the results of that cruise, particularly those which are already available.

2. In September 1955, the "Anton Dohrn" undertook another cruise investigating hydrographic and biological fishery problems (Fig. 2). This cruise led to the discovery of the "Anton Dohrn" Bank, with its rich redfish grounds.

3. In April 1957, the hydrographic and fishery biological cruise of "Anton Dohrn" was concentrated on the Greenland/Iceland Ridge (Fig. 3).

4. In March/April 1958, there followed the systematic survey for the IGY, which was planned to cover even more subjects than the first cruise and was directed towards the investigation of physical and chemical problems of water, towards planktology, bottom fauna, and the biology of fish (Fig. 4).

5. The next cruise in August/September 1958, was similar in cover to the IGY cruise late in winter, 1958 (Fig. 5). Already the first cruise had shown that the topography of the sea bottom, complicated in itself, was by no means sufficiently well known. An urgent necessity seemed to be the provision of reliable bathymetric charts, which again demanded a systematic survey of the sea. Fortunately, the director of the Hydrographic Institute in Germany, Dr. G. Böhnecke, agreed to such a survey, for he knew the particular conditions of this area from personal experiences on the "Meteor" cruises, 1929–1935.

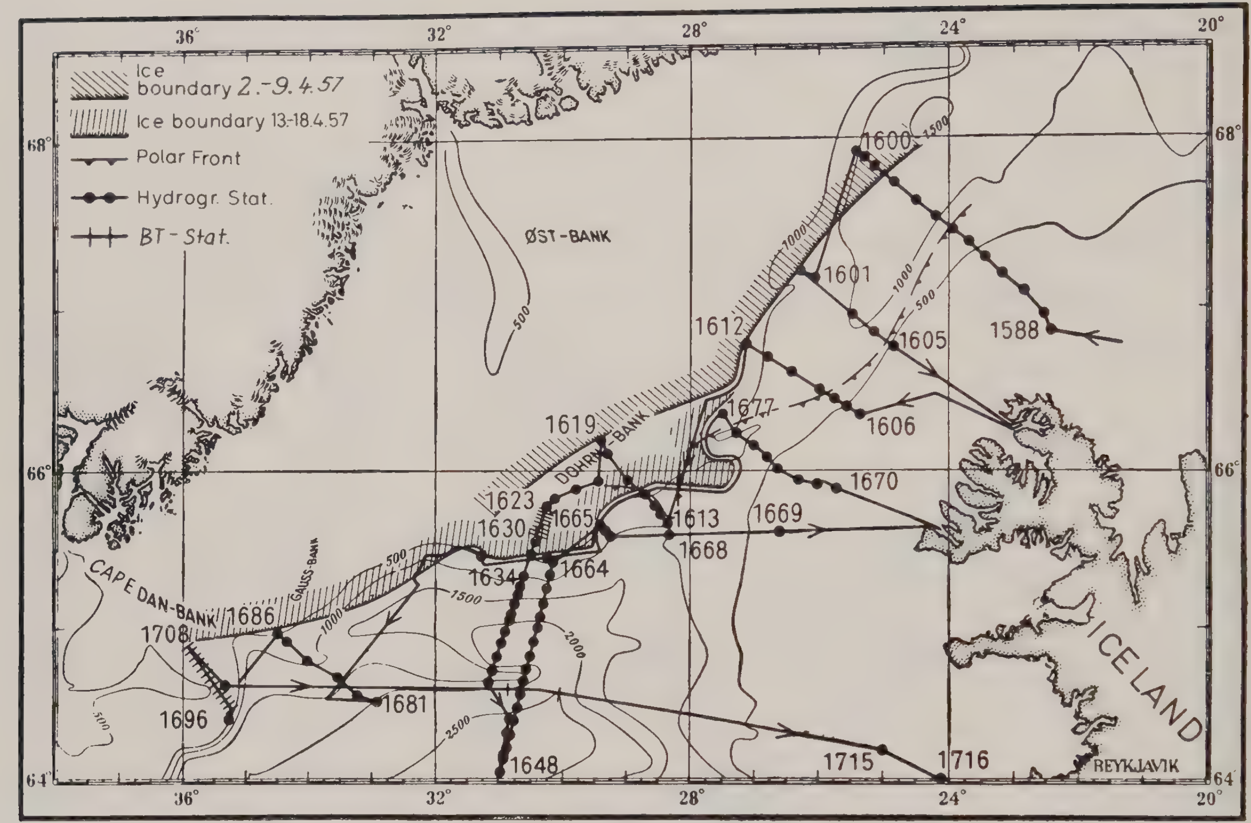
Ice boundary 2.-9.4.57
Ice boundary 13-18.4.57
Polar Front
Hydrogr. Stat.
BT-Stat.
36°
32°
28°
24°
20°
68°
66°
64°
ØST-BANK
DOHRN-BANK
GAUSS-BANK
CAPE DAN-BANK
ICELAND
REYKJAVIK
1600
1601
1605
1588
1612
1606
1619
1677
1670
1623
1630
1665
1613
1669
1668
1664
1634
1686
1708
1696
1681
1648
1715
1716
500
1000
1500
2000
2500

Figure 3.

6. Thus, in summer 1956, "Gauss" succeeded in surveying those parts of the Greenland/Iceland Ridge important for the fishery (Fig. 6). This was merely a surveying expedition and only a few hydrographical observations were made.

7. During the summer of 1957 the area south-west of Iceland was surveyed, including the Reykjanes Ridge, which is of particular interest from the geophysical point of view (Fig. 7).

2. The bottom topography

The elaboration of all available soundings resulted in the depth chart, shown in Figure 8. Examination of the main outlines shows that a trough, with a sill at a depth of about 650 m, crosses the Greenland/Iceland Ridge. Two deep prolongations of the Greenland fjords, the Store Fjord and the Sermilik Fjord, run across the broad East Greenland Shelf. Neither of them, however, ends in the deep sea. They are barred by a wall which is part of a larger wall, one flank of which runs continuously along the continental slope. This wall may be assumed to be a terminal moraine dating from the pleistocene. To this moraine belong the fishing banks, namely the "Anton Dohrn" Bank, the "Heimland" Ridge, and others. These banks are comparatively level, but further away, towards Greenland itself, the bottom configuration soon becomes complicated. The bottom was also found to be rough and for this reason fishing with a trawl was not possible. In this area bad fishing conditions were experienced and many nets were torn. South of 65°N the character of the shelf changes. It is only very narrow and the continental slope is very steep. This is shown clearly by the sounding section of Figure 9. Only on the very narrow strip at the edge of the East Greenland Shelf is it possible to fish by trawl. The soundings taken to date have been compiled in a large-scale depth chart 1 : 1 Mill., which was published as the Fishery Chart D 256 by the German Hydrographic Institute.

3. The hydrographical conditions

The absolute geopotential topography of the sea surface, which was evaluated with the aid of those observations made in June 1955 (G. Dietrich, 1957), indicates a great cyclonic current system near the surface (Fig. 10). The Irminger Current follows the Reykjanes Ridge, bifurcates north-west of Iceland into

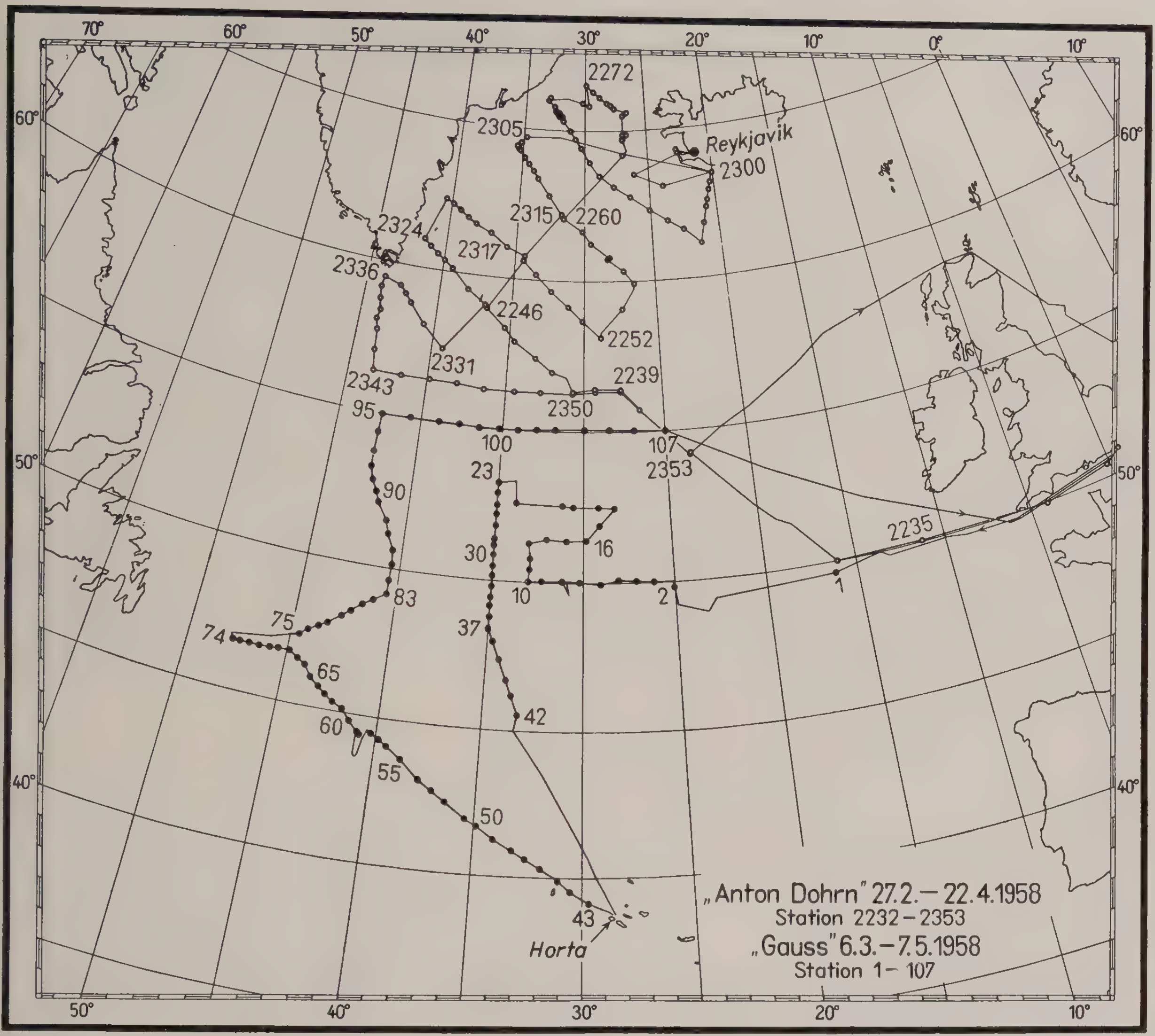
70°
60°
50°
40°
30°
20°
10°
0°
10°
60°
50°
40°
2272
2305
Reykjavik
2300
2315
2260
2324
2317
2336
2246
2252
2331
2239
2343
2350
95
100
107
2353
23
90
2235
30
16
10
2
1
83
75
74
37
65
42
60
55
50
43
Horta
„Anton Dohrn" 27.2.–22.4.1958
Station 2232–2353
„Gauss" 6.3.–7.5.1958
Station 1–107
50°
40°
30°
20°
10°

Figure 4.

the North Iceland Current and another branch which joins the East Greenland Current. These currents are reflected in the distribution of the surface temperature (Fig. 11). The warm Atlantic water of the Irminger Current divides into two warm branches which can be traced far beyond the north of Iceland and the east of Greenland. Notable is the thermic front in the East Greenland Current, where the temperature suddenly rises by 7°C over a distance of a few hundred metres. This is also reflected in the surface salinity (Fig. 12). The two branches of the highly saline Atlantic water are immediately adjacent to the East Greenland water of low salinity.

In greater depths the conditions become ever clearer. The great cyclonic eddy of the Irminger Current, marked by relatively high temperatures (Fig. 13), sends one branch to the north-east around Iceland and another to the south-west towards South Greenland. The great cyclonic whirl is the dominating phenomenon of this area and it may be assumed that the deep water, which is cold, is concentrated at its centre and rises to near the surface. This is seen in the long cross section from Cape Farewell to North Scotland, where in May/June 1955, the upper layer reaches a thickness of only a few metres (Fig. 14). This is not a unique case. When, in the autumn of the same year, the "Anton Dohrn" repeated the section from Farewell to northern Scotland, the result was the illustration shown

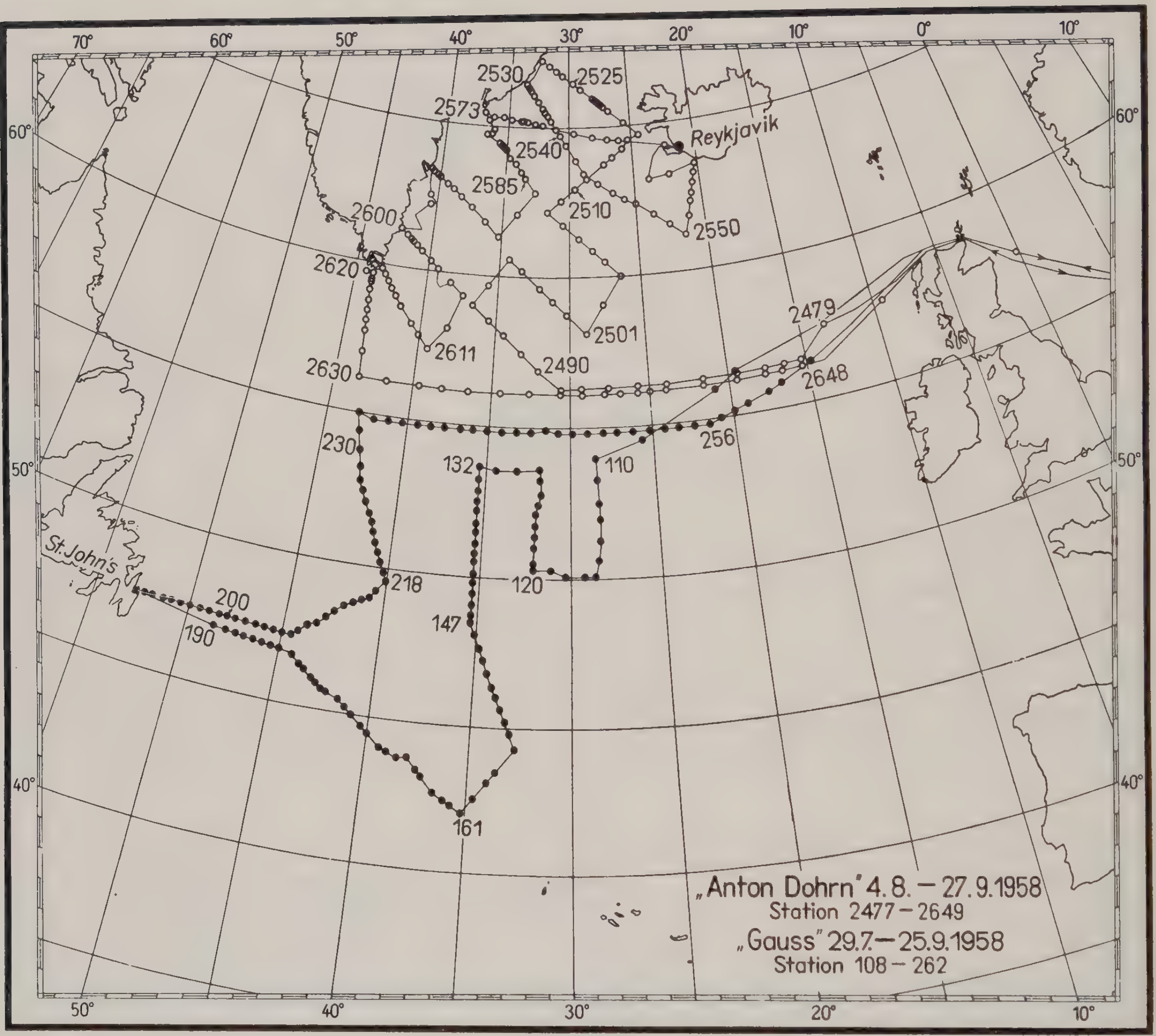
70°
60°
50°
40°
30°
20°
10°
0°
10°
60°
50°
40°
2530
2525
2573
Reykjavik
2540
2585
2510
2550
2600
2620
2479
2501
2611
2490
2630
2648
230
256
132
110
St. John's
218
120
200
147
190
161
„Anton Dohrn" 4.8. – 27.9.1958
Station 2477 – 2649
„Gauss" 29.7. – 25.9.1958
Station 108 – 262
50°
40°
30°
20°
10°

Figure 5.

in the lower half of Figure 14: the highest position of the isotherms was still in the central Irminger Sea, whence they sink into greater depths on both sides. The Mid-Atlantic Ridge is thus within the reach of the warm Atlantic water. The distribution of the chemical components corresponds with these conditions. If the distribution of the phosphates in solution is considered in the section of June 1955, a relatively high percentage of dissolved phosphates is found, with a maximum in the central Irminger Sea. There is also plenty of oxygen, at least in those layers which concern the fisheries. The vertical distributions of both phosphate and oxygen have been discussed by Kalle (1957).

To complete the outline sketch of the hydrographic conditions some remarks are necessary about the surface turbidity, as deduced by Joseph (1959) from the recordings made during the cruise of May/June 1955 (Fig. 15). On this chart, the more densely an area is hatched, the more the coefficient of extinction differs from that of pure water and the more turbid, therefore, is the water. It may be added that this turbidity was predominantly of organic origin. The darker an area is hatched, the richer it is in plankton. In particular the plankton was very rich in species. This integrating optical method does not, of course, reveal which species of plankton caused the turbidity in the specific areas. M. Gillbricht (1959) investigated this part of the problem and was able to demonstrate that

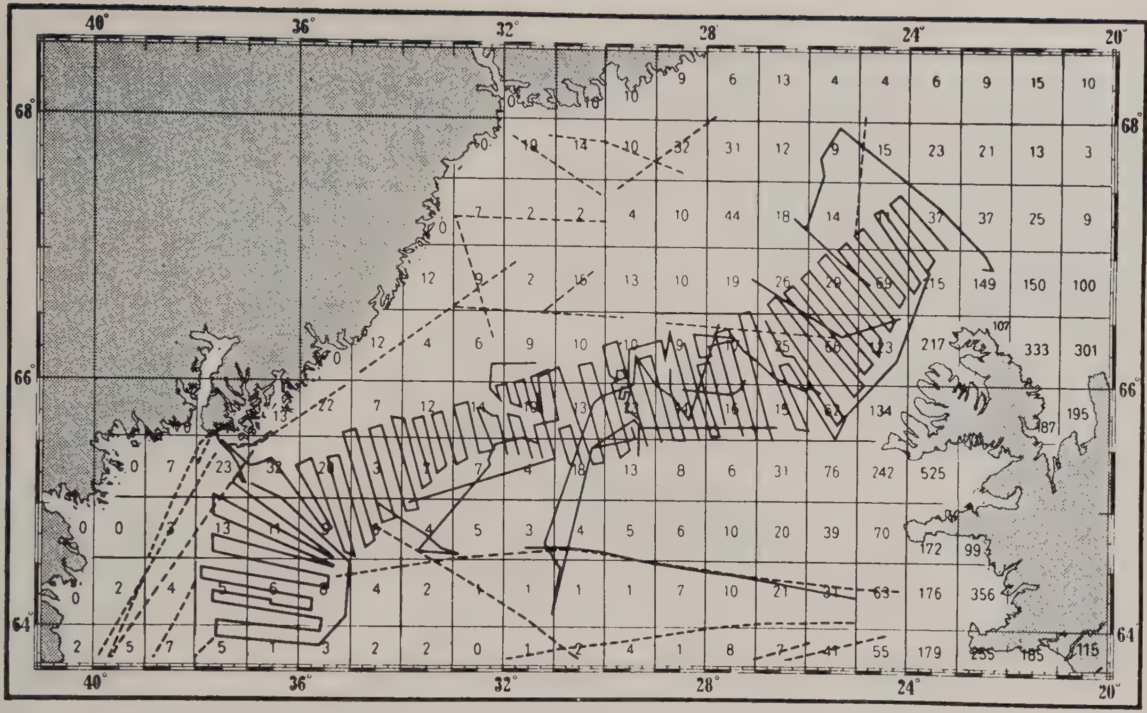

Figure 6.

the patch of dense plankton south-west of Iceland consists chiefly of zooplankton and detritus from a previous phytoplankton outburst.

In the whole area of the Irminger Sea, which, as will be seen later, is of special importance for the biology of redfish, the East Greenland Shelf is of outstanding importance, because it is in this region that the main redfish grounds are to be found. For this reason some hydrographical details of the shelf must be discussed.

Three temperature sections of the area of the Greenland/Iceland Ridge reveal the remarkable facts evident in Figure 16. In the north the cold Polar water covers the shelf down to the bottom. In particular, it is divided into two cold currents, that is to say, two East Greenland Currents, as Krauss (1958a) has already pointed out. One of them runs along the coast, the second along the edge of the transverse trough. The latter is clearly distinguished from the warm Atlantic water. Farther to the south the heavy, and at the same time, warm waters move slowly over the bottom towards Greenland. In this way, and this is a most essential feature, relatively high bottom temperatures occur, which reach 4°–5°C. This process extends still further to the south. The East Greenland Current is thus only a surface phenomenon. It remains bifurcated only over the Greenland/Iceland Ridge; southwards, however, it joins into one current. Due to the predominance of

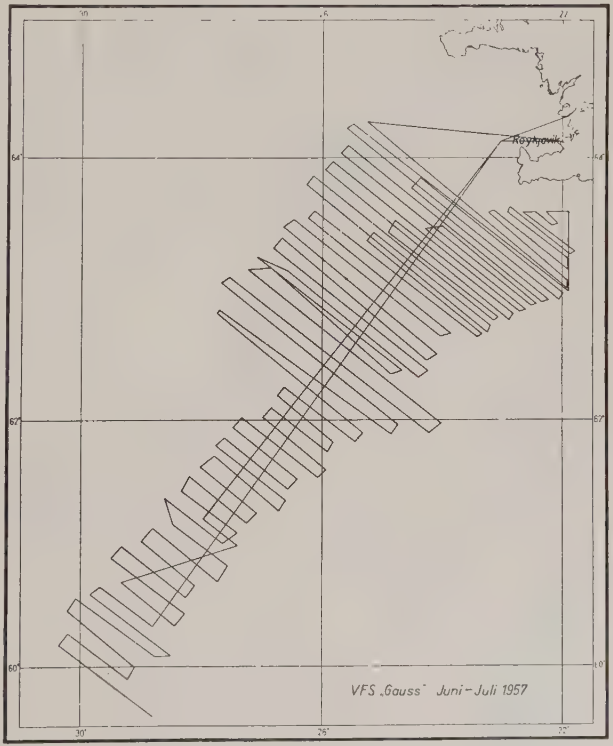

Figure 7.

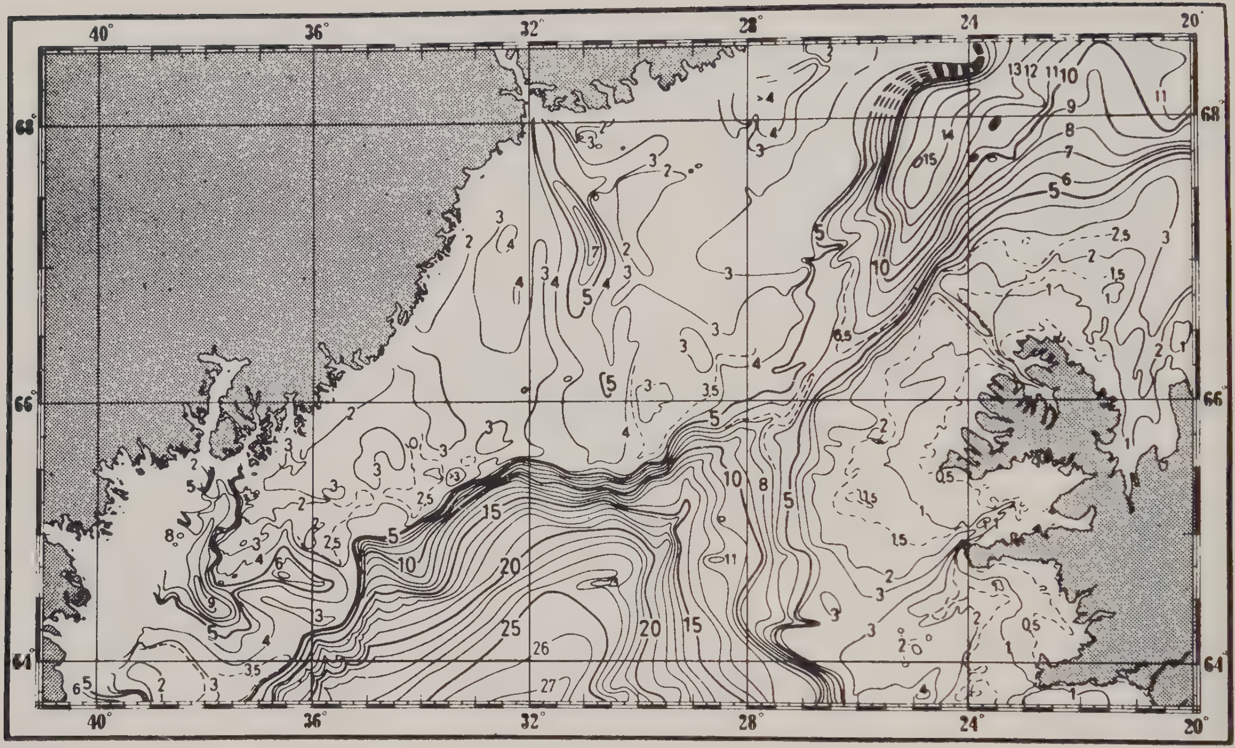
40°
36°
32°
28°
24
20°
68°
66°
64°

Figure 8.

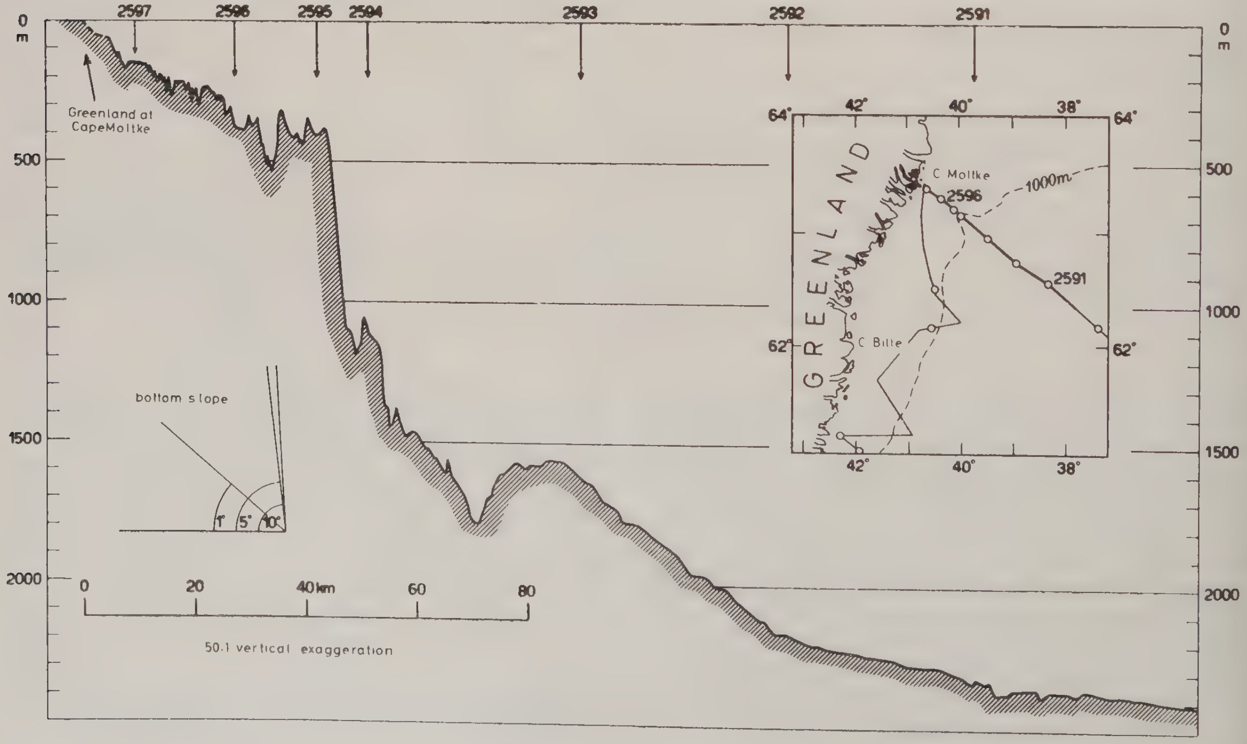

Figure 9.

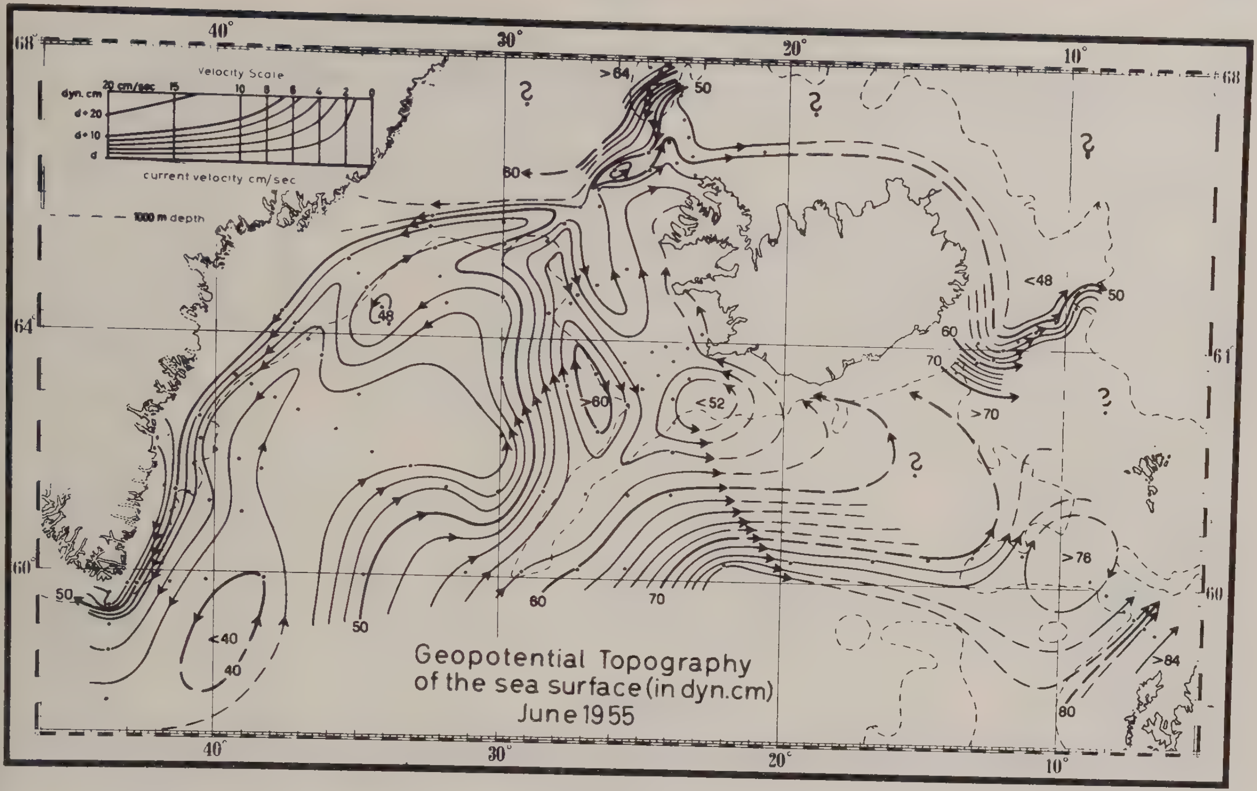
40°
30°
20°
10°
68°
68
64°
64
60°
60
Velocity Scale
dyn.cm
20 cm/sec
15
10
8
6
4
2
0
d+20
d+10
d
current velocity cm/sec
1000 m depth
>64
50
80
48
>80
<52
<48
50
60
70
>70
>76
50
<40
40
50
60
70
80
>84
Geopotential Topography
of the sea surface (in dyn.cm)
June 1955

Figure 10.

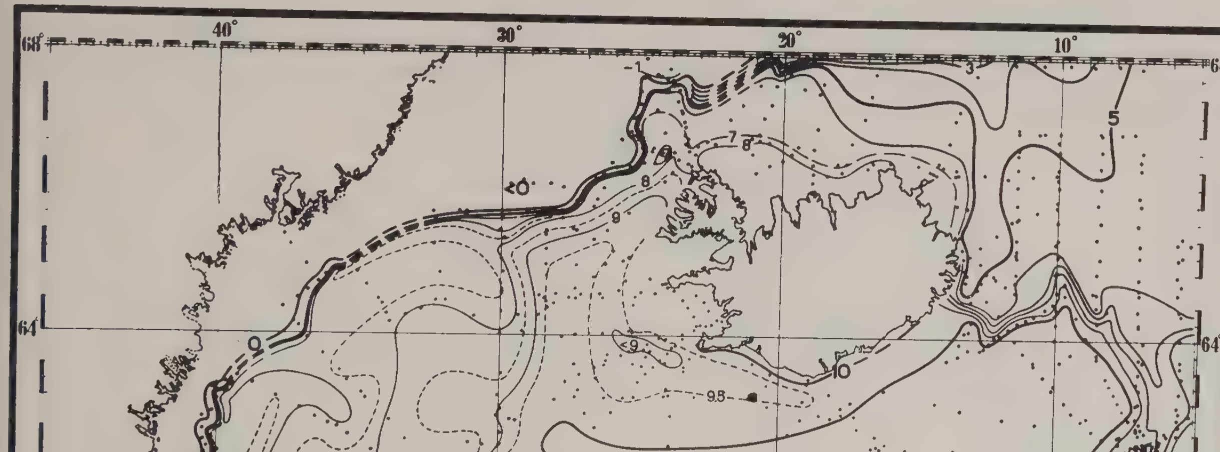
40°
30°
20°
10°
68°
64°
60°
-1
3
5
7
8
<0
8
9
0
<9
9.5
10
10
<0
5
8
8.5
9
10
>11
11
10
t° in 0m
Juni 1955

Figure 11.

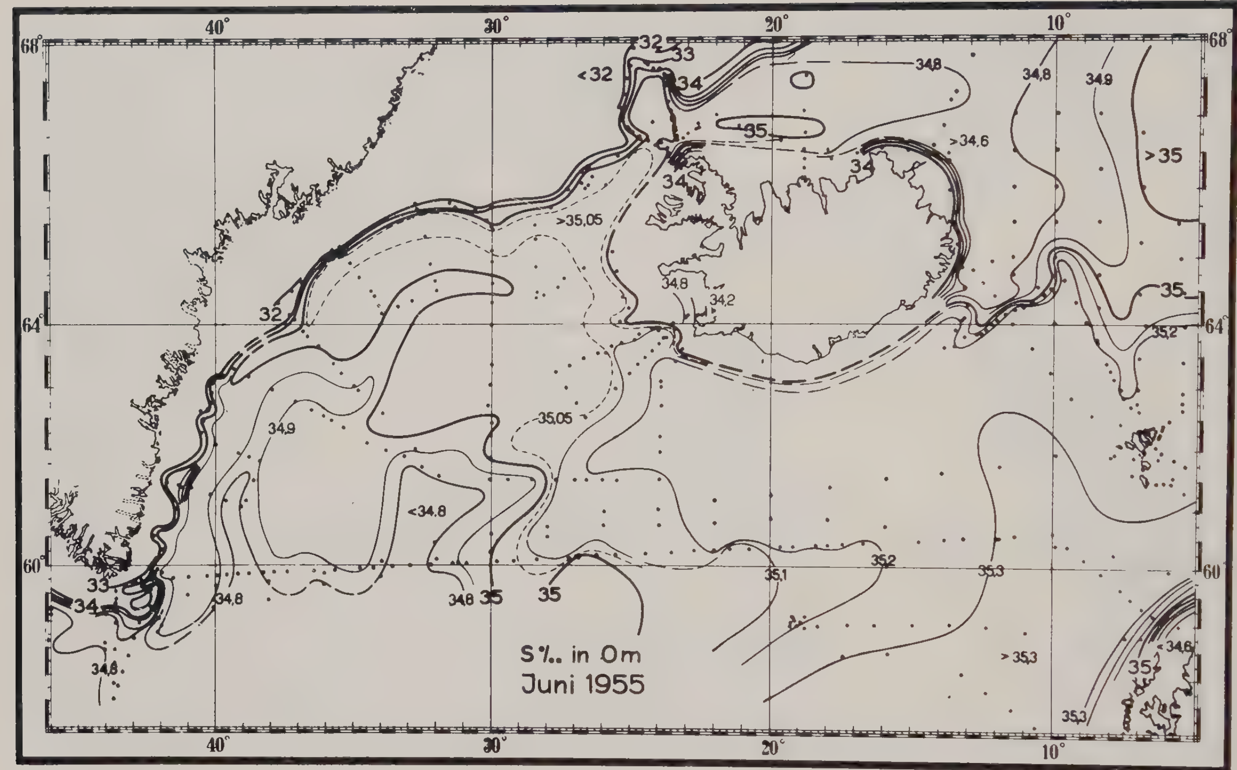
S‰ in 0m
Juni 1955
40°
30°
20°
10°
68°
64°
60°
<32
32
33
34
34,8
35
>34,6
34,9
>35
>35,05
35,05
34,2
34,9
<34,8
35,1
35,2
35,3
>35,3
34,6
35

Figure 12.

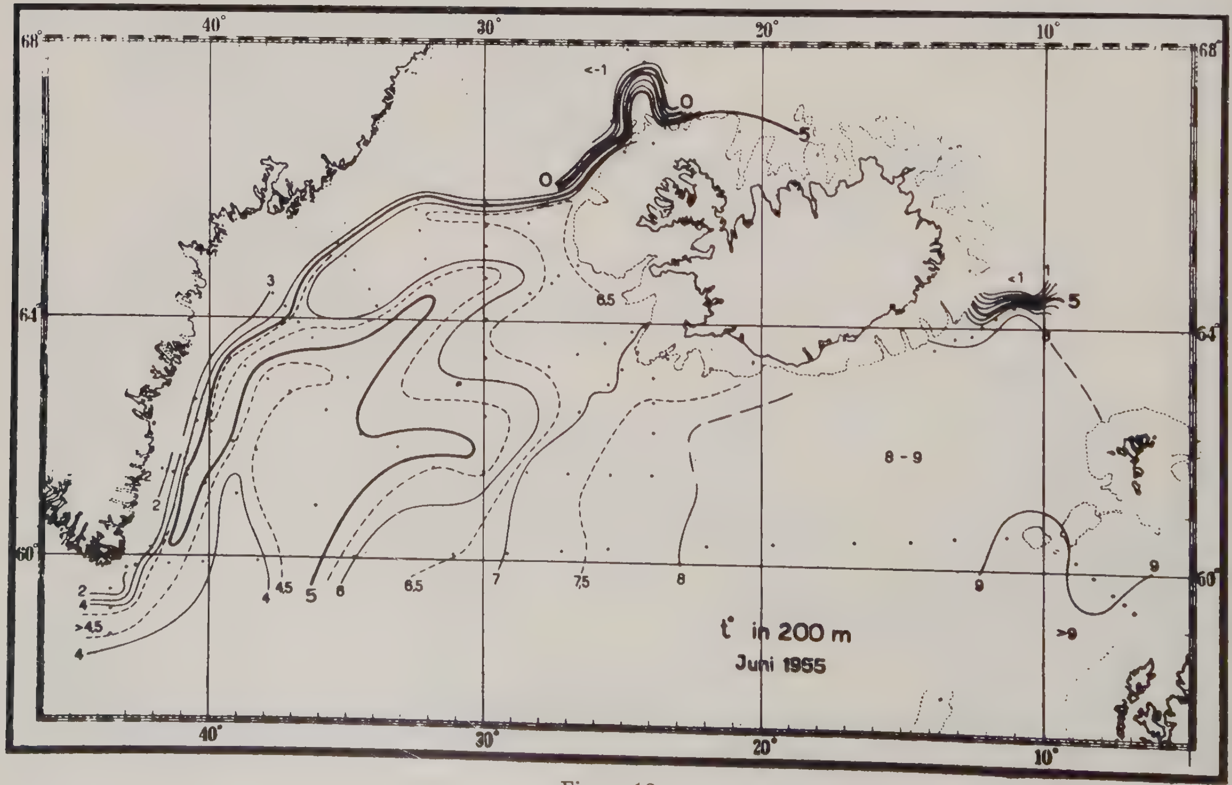
t° in 200 m
Juni 1955
40°
30°
20°
10°
68°
64°
60°
<-1
0
5
<1
3
6,5
8 - 9
2
4
>4,5
4,5
6
7
7,5
8
9
>9

Figure 13.

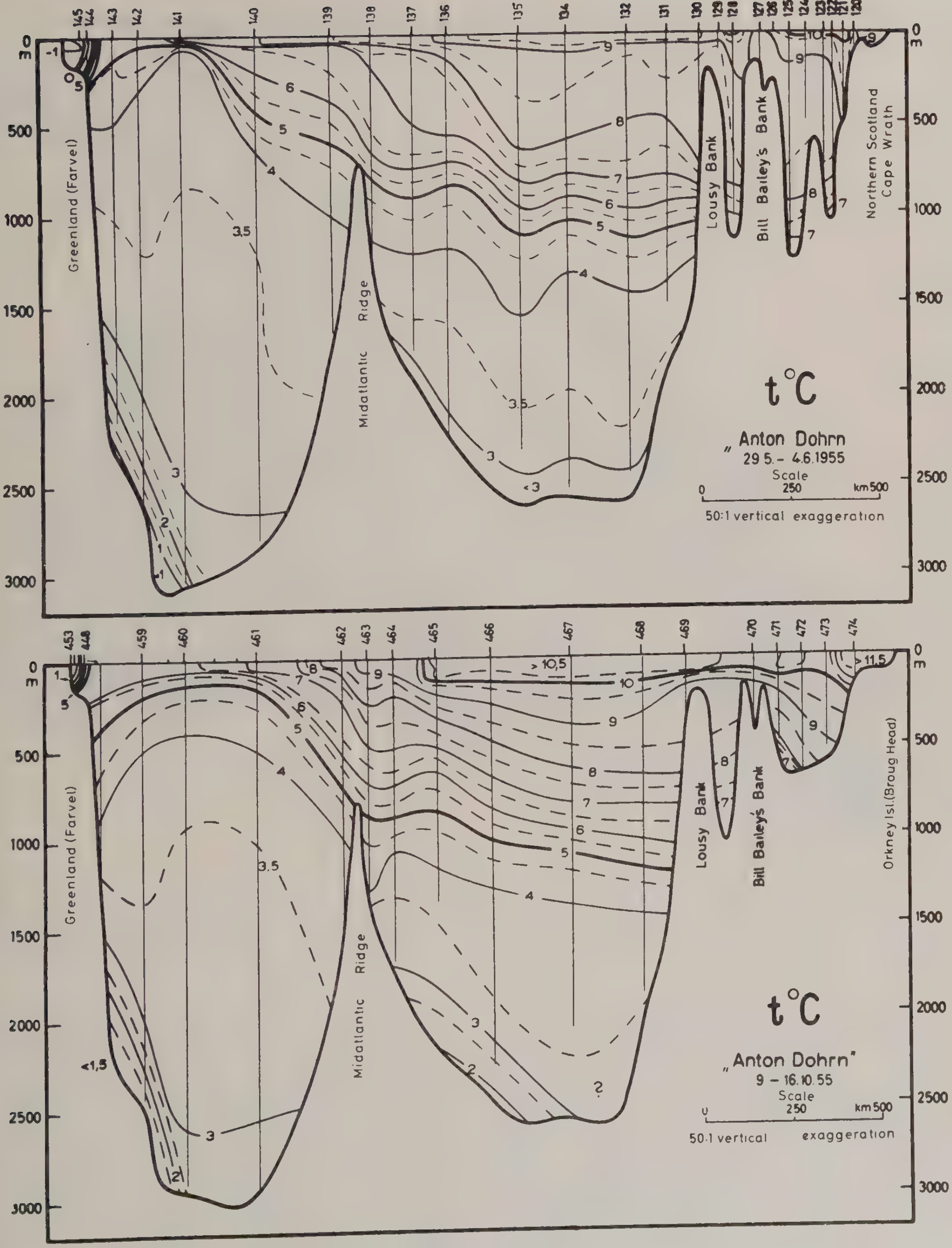
145 144 143 142 141 140 139 138 137 136 135 134 132 131 130 129 128 127 126 125 124 123 122 121 120
0 m
500
1000
1500
2000
2500
3000
Greenland (Farvel)
Midatlantic Ridge
Lousy Bank
Bill Bailey's Bank
Northern Scotland Cape Wrath
-1
0
5
6
5
4
3,5
9
8
7
6
5
4
3,5
3
<3
10
2
1
t°C
„Anton Dohrn"
29.5.- 4.6.1955
Scale
0 250 km 500
50:1 vertical exaggeration
453 448 459 460 461 462 463 464 465 466 467 468 469 470 471 472 473 474
Greenland (Farvel)
Midatlantic Ridge
Lousy Bank
Bill Bailey's Bank
Orkney Isl. (Broug Head)
> 10,5
10
> 11,5
9
8
7
6
5
4
3,5
3
2
<1,5
t°C
„Anton Dohrn"
9 – 16.10.55
Scale
0 250 km 500
50:1 vertical exaggeration

Figure 14.

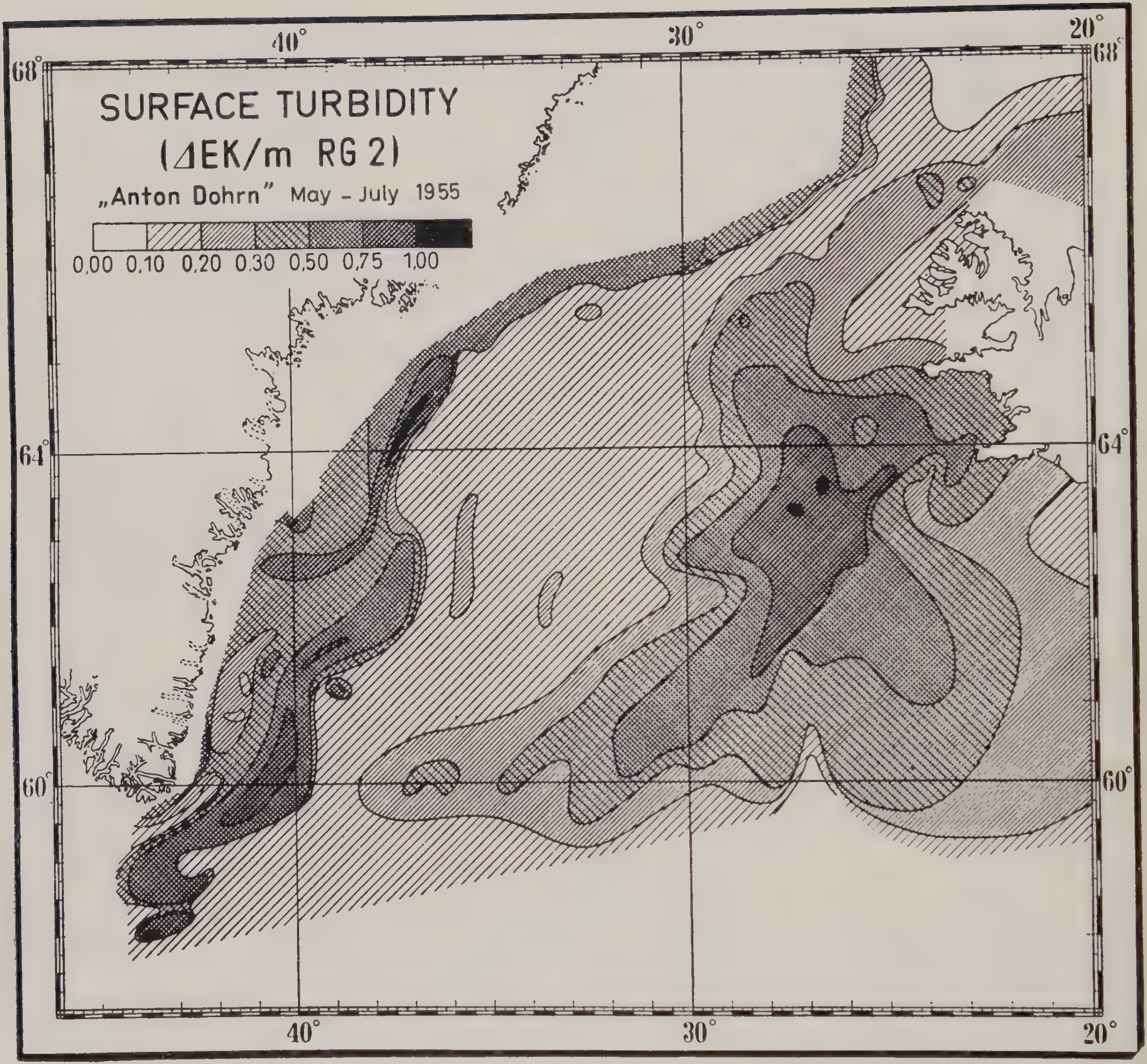

Figure 15.

the melt water in this area, the salinity is reduced in the surface layer (Fig. 17); near the bottom it reaches 34·8–34·9 $^0/_{00}$. As far as salinity is concerned, therefore, the fishing grounds are relatively uniform.

Of remarkable importance are the two fjord troughs mentioned in the discussion of the topography. It becomes evident that the relatively warm Atlantic water enters these troughs primarily from their eastern ends (Fig. 18) and advances almost as far as Greenland, circling round the banks in a clockwise direction, a fact well known in the northern hemisphere as a consequence of the Coriolis force. In this way the shelf obtains its distinct thermal gradients, which certainly are of some importance for the fish on the bottom.

A diagrammatic representation of the surface currents is given in Figure 19. There are the two East Greenland Currents and the Irminger Current, which bifurcates north-west of Iceland, moving to the southwest together with the outer branch of the East Greenland Current. What seems here to be a stationary, that is to say a permanent, arrangement of layers and movements, is certainly not permanent at all. Clear evidence of this is given by the distribution of surface temperature (Fig. 20) which was measured over a short period

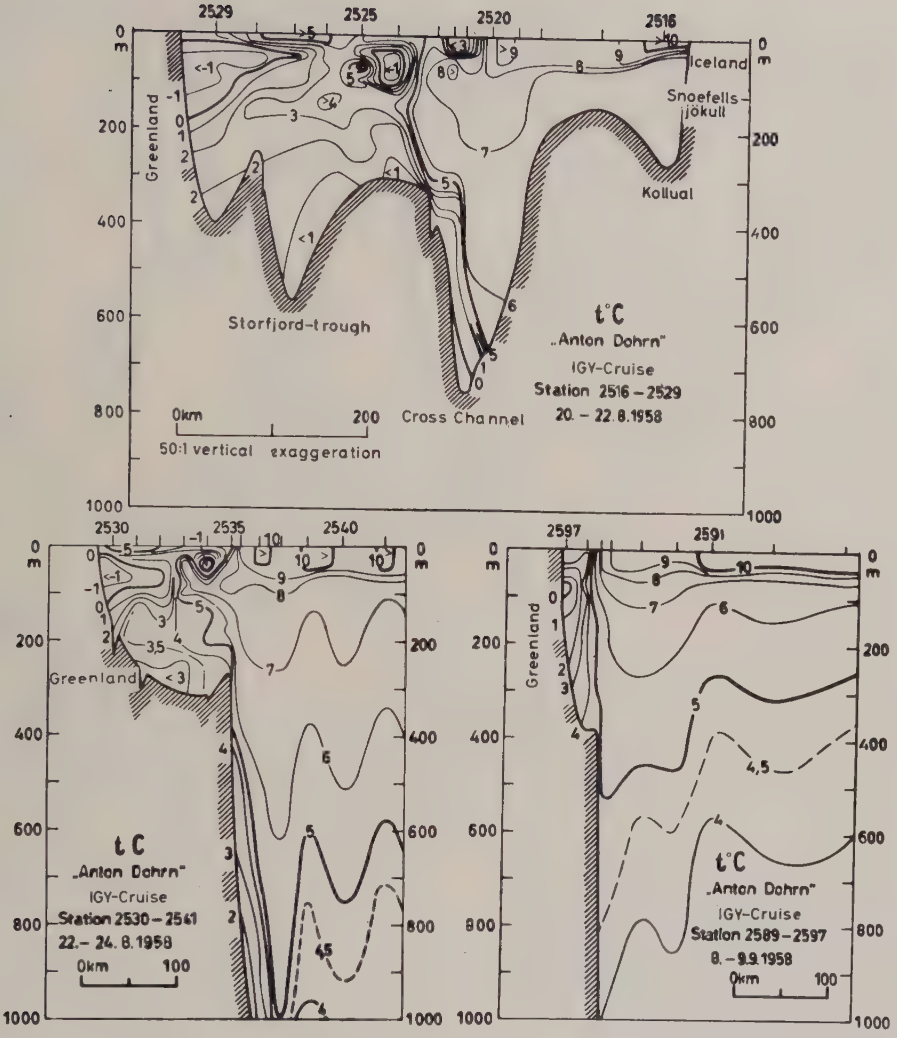

Figure 16.

y the "Gauss" during the survey in summer 1956 (Fig. 6). What was originally thought of as a set of early straight, tightly packed isotherms, and consequently as a narrow current, changes into a strongly neandering band. The current meanders accordingly. t should be noted that the edge of the shelf represents he central axis of these meanderings, which means hat the East Greenland Current also meanders. The neanderings are not stationary, however, but move lowly in the direction of the main current, theoretically vith $^1/_{10}$ of the current velocity. The picture of the arious layers and currents thus developed proves to be ar from simple, though, in its essential parts, it is quite nderstandable today. The question arises how this nowledge may be used successfully to help with the iology of redfish.

4. The distribution of redfish larvae

Considering first the larval stage, as mentioned before, on some of the cruises, namely of the three out of seven, systematic hydrobiological surveying was attempted, including systematic fishing for larvae. The distribution of these larvae, based on hauls from different depths with the Helgoland larva net made on three of the seven cruises mentioned above, are represented in Figure 21. Their distribution in the Irminger and Labrador Seas was studied in three different seasons: in late winter (March/April 1958), in spring (May/June 1955), and in late summer (August/September 1958).

(a) March/April 1958. Except for one catch on the Newfoundland Bank, which was rich in larvae of the American rosefish (211 larvae/m²), only small

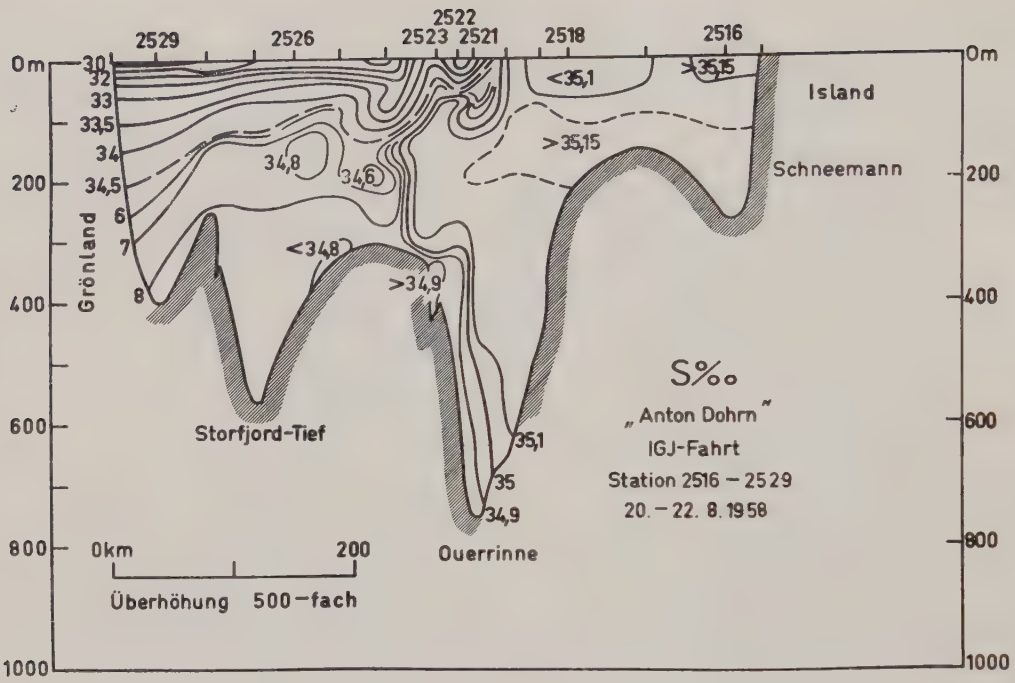

Figure 17.

numbers of redfish larvae were found in the area of the Reykjanes Ridge (3–60 larvae/m²). The reason for this may lie in the fact that the breeding period was only just beginning. But another observation was quite remarkable: Over the greater part of the Irminger Sea the upper layers down to 500 m were free of *Calanus finmarchicus* – surely an important food organism for the larvae. In May of the same year Einarsson (this volume) found no indications of larvae on the echo-sounder records in the Irminger Sea, contrary to experience at the same time in other years.

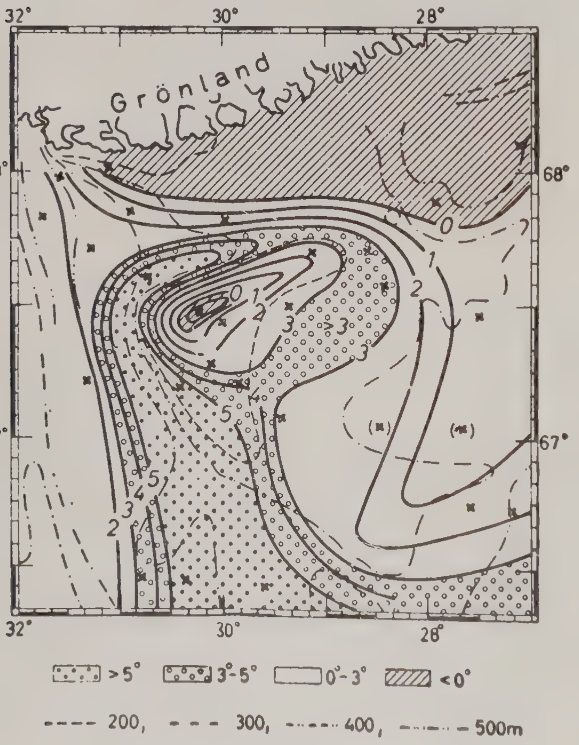

Figure 18.

(b) In May/June 1955, redfish larvae were distributed over a wide region (Fig. 21). The highest frequency was obtained in the area of the Reykjanes Ridge (39 larvae/m²).

(c) By August/September 1958, the larval stage was almost completely over, and hauls in the Irminger Sea had negative results.

To return to the findings of May/June 1955. In this case the observations from the first systematic cruise with "Anton Dohrn" in the Irminger Sea were made during the main breeding period. Other physical and biological observations of this cruise are now available.

Hauls from different depths proved that the larvae were concentrated in the upper 50–100 m. It is, however, difficult to give a clear correlation with other factors. The current, which is weak (see Fig. 10), can hardly be a convincing reason. There is a correspondence with the statement of Tåning (1949), that the breeding places of redfish are to be found where boreal surface water, with temperature of 8°–9°C, does not reach deeper than 200 m, and cold deep water of

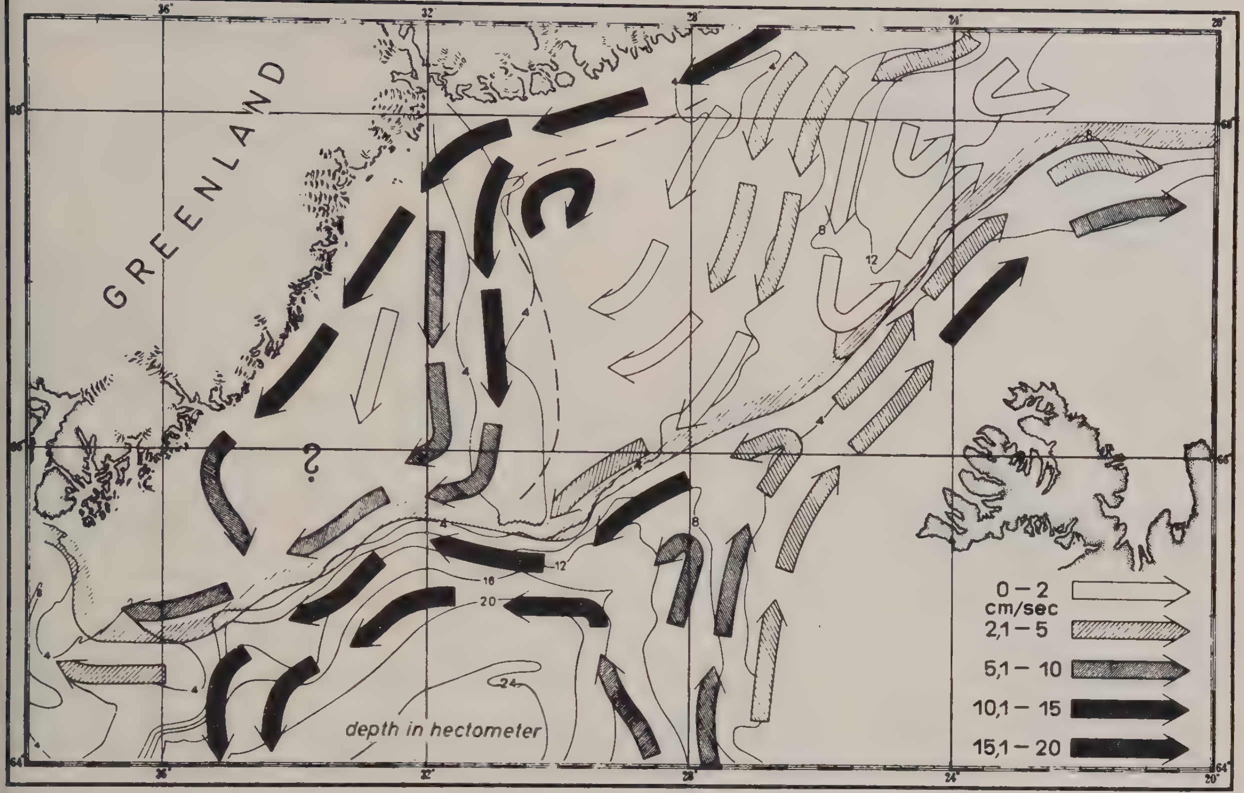

Figure 19.

3°–4°C lies deeper than 200–500 m. In the present case this condition is fulfilled in the area of the Reykjanes Ridge (see Fig. 14). Water with temperature of 4°–8°C lies between 50 and 1000 m. Eastwards of the ridge the 8°C isotherm sinks below 500 m depth and westwards the 4°C isotherm approaches the surface; both of the latter conditions would exclude breeding places of the redfish.

There are, however, also two other conformities, that is, with the distribution of the turbidity of the water (see Fig. 15) and with the distribution of *Aglantha* (see Fig. 21). It has been mentioned already that in this case, according to the planktological findings, this area of high turbidity was rich in zooplankton and detritus. It is possible that an appropriate feeding-basis for redfish larvae does exist here. This interpretation is supported by the observation that the areas with redfish larvae correspond with high densities of *Aglantha*. This is a point in favour of the theory that the redfish chooses as breeding places areas with good nourishment for the larvae. Hypotheses on the causes of this organic production associated primarily with the Reykjanes Ridge do exist (Joseph, 1959). It seems that this phenomenon of upwelling described by Joseph does not occur regularly every year nor at the same time in the year. This would explain the absence of larvae in the Irminger Sea in 1958 during March, and the findings of Einarsson (p. 199) that there is not a constant position for the breeding grounds every year.

5. The distribution of adult redfish

Considering the adult redfish on the new fishing grounds of East Greenland, all results of the test catches, comprising more than a hundred hauls, were mapped on a transparent paper covering the new fishery chart. The data, based mainly on the list compiled by Kotthaus and Krefft (1957) include the depth of water and the weight of redfish caught (in kg); the bottom temperatures were treated separately. It is difficult to give these results exhaustively and they are therefore summarized in a few short sentences, firstly for the relationship between redfish and hydrographic conditions, which can be gathered from what has been stated above and from the facts contained in these charts. Ten test catches of the "Anton Dohrn" in the northern part of the Greenland/Iceland Ridge showed that no high catches of redfish were taken when the bottom temperatures were below 2°C. The redfish, therefore, seem to avoid temperatures below 2°C. Although, apart from these ten hauls, three rather

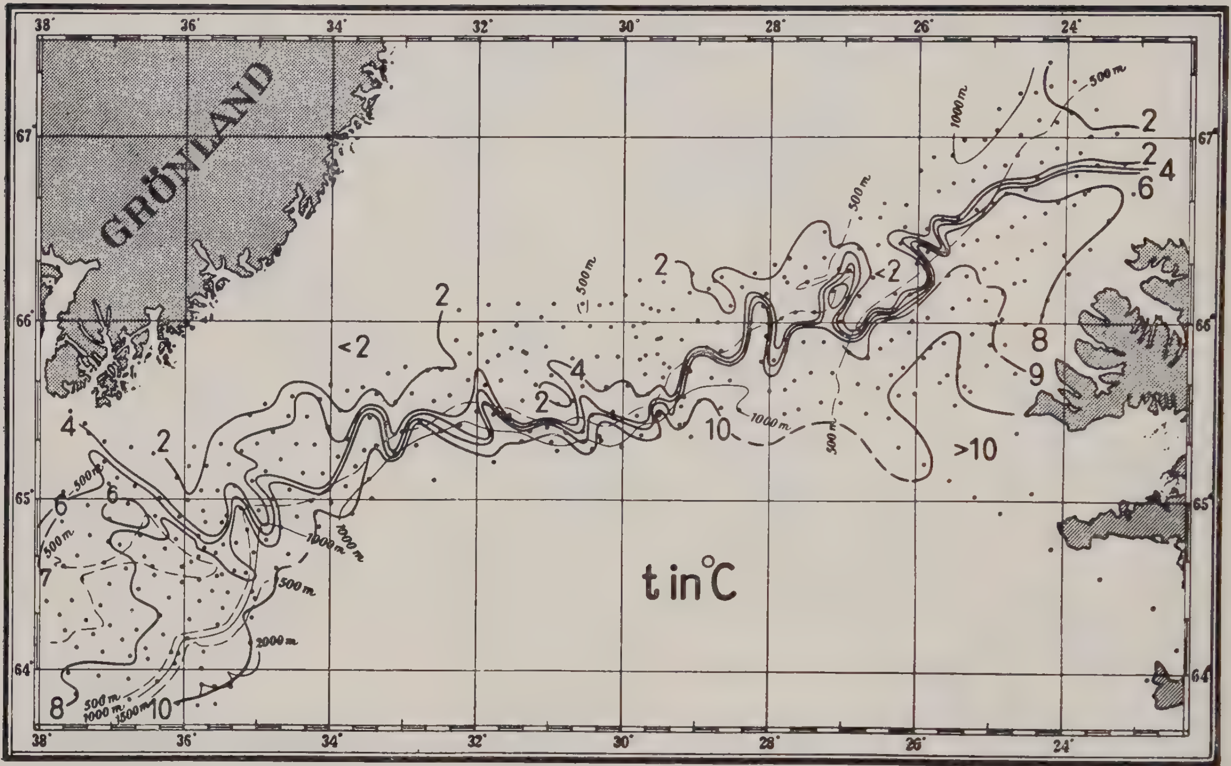
GRÖNLAND
t in°C
38° 36° 34° 32° 30° 28° 26° 24°
67° 66° 65° 64°
2
<2
>10
4
6
7
8
9
10
500 m
1000 m
1500 m
2000 m

Figure 20.

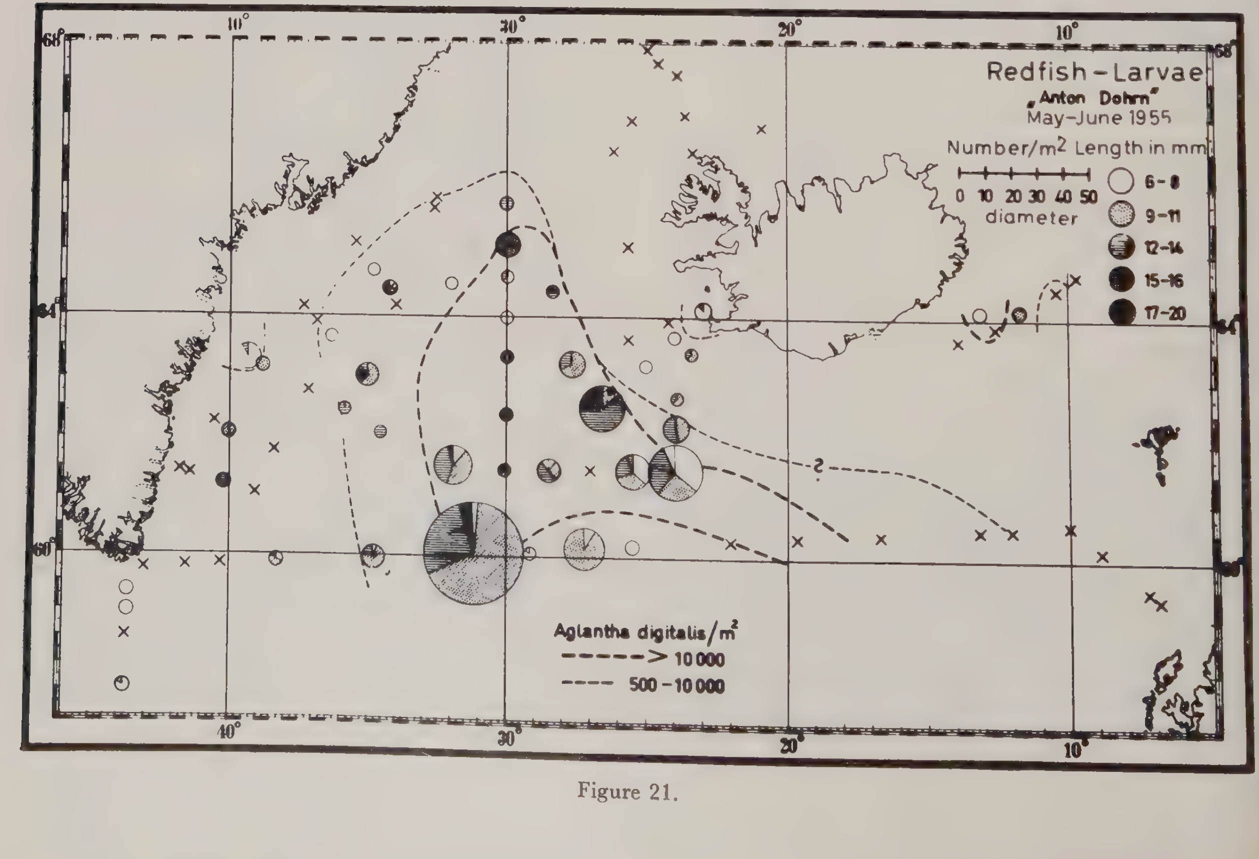
Redfish–Larvae
„Anton Dohrn"
May–June 1955
Number/m2 Length in mm
0 10 20 30 40 50
diameter
6–8
9–11
12–14
15–16
17–20
Aglantha digitalis/m²
-----> 10 000
---- 500–10 000
40° 30° 20° 10°
68° 64° 60°

Figure 21.

heavy ones were made at temperatures of 0·4°, 1·0°, and 1·3°C respectively, this is not necessarily contradictory evidence, for they were made immediately at the polar front where, as has already been seen, the temperature suddenly changes by several degrees within a short distance. The remaining part of the Greenland Shelf had bottom temperatures of 3°–5°C, and the Iceland Shelf temperatures were of 5°–7·5°C. In these areas there was obviously no correlation between redfish and bottom temperatures. There were rich hauls as well as complete failures at the same temperatures.

Another relationship – not with hydrography, but with the topography of the sea bottom – must be recognized on the Greenland Shelf. The rich hauls were almost exclusively confined to the edge of the shelf, to the wall mentioned in the discussion of the bottom topography as a probable terminal moraine. In this special case the preferred area included also the edges of the two great fjords, the Store Fjord and the Sermilik Fjord, when temperatures were above 2°C. The exact reasons for the correlation with the topography of the sea bottom can hardly be defined with certainty, and the following hypothesis is put forward tentatively. The results of the systematic survey leave no doubt hat the bottom of the marginal wall is comparatively evel. Further landwards, the configuration becomes rugged. It consists partly of polished smooth rock, partly of deep depressions filled with soft mud, the ediments of glacial meal. This area is very dangerous or the use of trawl gear and as was stated earlier, uriosity was rewarded with torn nets! This area is not t all suited for commercial trawling. Moreover, ccording to the few successful trawl catches, the red-ish seems to avoid these shelf-plains. It must be ssumed that the icebergs which in this area frequently ouch the bottom, destroy much of the bottom fauna. lthough the redfish does not live on this fauna irectly, its feeding depends largely upon animals living n the bottom fauna. Whatever the reasons for the oncentration of redfish may be, it was obvious from he first cruise in this area, in 1955, that the bottom opography plays an important and decisive part, and n consequence Germany undertook the first and most rgent step: a contribution to an exact survey of the opography.

Summary

The main features of the bottom topography (Figs. 9) and of the distribution of temperature, salinity, urbidity, and currents in the Irminger Sea and on the reenland/Iceland Ridge (Figs. 10–20) are explained, ased on seven research cruises of “Anton Dohrn” and Gauss” 1955–1958 (Figs. 1–7). The comparison beveen the distribution of redfish larvae (Fig. 21) and e distribution of turbidity (Fig. 15) shows a remarkable agreement. Both reach high values in the region of the Reykjanes Ridge, south-west of Iceland. The comparison of the natural environment with the results of more than a hundred test trawl hauls proves that the adult redfish avoids bottom waters colder than 3°C, the only exceptions being very close to the boundary of the warm Atlantic water. In areas with bottom temperatures between 3° and 7·5°C there is obviously no correlation between redfish distribution and bottom temperature. In these areas the adult redfish prefers the shelf edge.

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3.

Some Observations on the Redfish of the Labrador Region

By

K. FREUND

Institut für Hochseefischerei und Fischverarbeitung, Rostock-Marienehe

During 1958 there was a great increase in the interest shown by some European countries in the fishing area of Labrador. In the autumn of that year the opportunity was taken to make some observations on the redfish stock in this area. The fishing grounds were between 53°02′ to 53°06′N and 52°15′ to 52°30′W, and the depth between 280 and 310 m. The temperature (end of October 1958) of the bottom water was 3·8° to 3·9°C. At 250 and 200 m the temperature had decreased to 2·3° and 2·1°C respectively, whilst at the surface it was 3°C.

Three samples of redfish were taken on board a commercial trawler on the fishing grounds (28. Oct., 30. Oct., 3. Nov. 1958), whilst two further samples were measured later at the port of landing (7. Jan., 7. Feb. 1959).

Both *Sebastes marinus* and *S. mentella* occurred in the catches, but the composition of the catches varied from 0·95 to 14·46 % of *marinus*. Thus the *mentella*-type redfish was by far the predominant form. No difficulty was experienced in differentiating between the two forms. They could be separated by means of colour, by the process of the lower jaw (this, however, was not quite so pronounced in these *mentella* from the Labrador area as in those of the Bear Island region), and by the orbit's diameter. For the *mentella*-type redfish the means of these observations are summarized in Table 1.

Table 1

Sex composition and mean length of *mentella*-type redfish from the Labrador region

Day of catch	Sex composition ♂♂ (%)	Mean length (cm) ♂♂	♀♀	Total	n
28. Oct. 1958	48·13	33·67	37·34	35·57	401
30. Oct. 1958	51·91	33·47	36·34	34·85	418
3. Nov. 1958	54·55	32·97	36·76	34·69	528
7. Jan. 1959	55·01	34·04	41·75	37·50	349
7. Feb. 1959	59·52	35·50	42·08	38·16	331

(The aberrant mean length in the samples of the 7.1. and 7.2. 1959 may be due to the handling or sorting of the catch in the commercial fishery.)

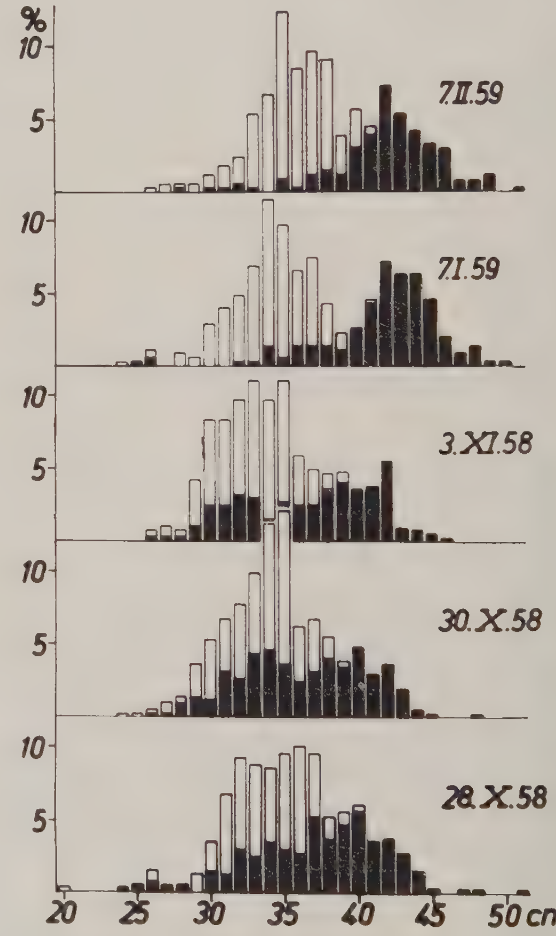

Figure 1. Length distribution of *mentella*-type redfish from the Labrador region (October 1958 – February 1959); males white, females black.

The mean length and especially the length distribution (Fig. 1) of *mentella* redfish clearly differs from the corresponding values in the "Kopytov" area (south of Bear Island) during the main fishing season April–June. In this latter locality the peak is at 38–40 cm,

Table 2
Body length and otholith weight of redfish of the Labrador region (Oct. 1958—Feb. 1959)

(In brackets: *S. marinus*)

Body length (cm)	n	Otolith weight (mg)		
		Mean	Minimum	Maximum
25	1 (–)	123 (–)	– (–)	– (–)
26	6 (–)	149 (–)	128 (–)	170 (–)
27	4 (–)	156 (–)	142 (–)	162 (–)
28	12 (–)	161 (–)	135 (–)	195 (–)
29	15 (–)	171 (–)	153 (–)	197 (–)
30	25 (1)	176 (134)	159 (–)	210 (–)
31	13 (1)	186 (142)	169 (–)	218 (–)
32	20 (1)	211 (146)	176 (–)	251 (–)
33	18 (2)	237 (147)	193 (140)	302 (153)
34	13 (2)	268 (153)	231 (150)	312 (156)
35	35 (1)	278 (180)	210 (–)	333 (–)
36	29 (4)	283 (170)	248 (155)	370 (187)
37	15 (5)	290 (171)	227 (154)	319 (188)
38	22 (4)	325 (187)	253 (171)	424 (204)
39	10 (1)	348 (251)	290 (–)	425 (–)
40	13 (6)	350 (217)	307 (205)	424 (230)
41	9 (5)	359 (215)	300 (198)	403 (236)
42	16 (–)	394 (–)	333 (–)	470 (–)
43	26 (4)	402 (257)	345 (226)	479 (301)
44	16 (1)	427 (220)	346 (–)	506 (–)
45	15 (6)	451 (265)	353 (222)	568 (312)
46	7 (1)	496 (263)	389 (–)	579 (–)
47	2 (2)	472 (310)	429 (305)	514 (314)
48	2 (5)	527 (300)	423 (274)	631 (316)
49	4 (1)	519 (288)	478 (–)	578 (–)
0	1 (2)	523 (312)	– (296)	– (327)
1	– (2)	– (332)	– (323)	– (341)
2	– (1)	– (308)	– (–)	– (–)
4	– (1)	– (302)	– (–)	– (–)
5	– (1)	– (455)	– (–)	– (–)
1	– (1)	– (473)	– (–)	– (–)

with a steep decline on both sides. At Labrador (October–February) the bulk of the samples were spread over a more extended range. Here the separation of the sexes by length was more evident, with the maximum lengths of the females and males at 51 and 41 cm respectively.

The sex ratio and also some other observations (e.g. condition of gonads) seemed to indicate that the shoals were formed for the purpose of mating. Feeding was intensive; nearly all stomachs were full. The scopelid *Maurolicus mülleri* was very frequently observed in the stomachs. Fat was abundant in the body cavity.

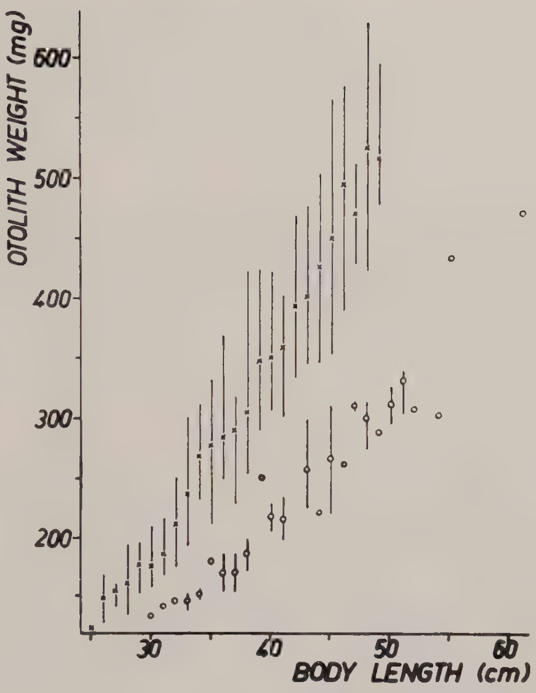

Figure 2. Body length and otolith weight (mean and variation) of redfish from the Labrador region. x=*mentella*, o=*marinus*.

As has been observed in other areas, the relation between body length and otolith weight in the *mentella*-type redfish is different from the *marinus*-type in the Labrador area too. In Figure 2 the values for the otolith weight are plotted against the body length (see Table 2). It will be seen that the otolith weights are somewhat lower for a given length in *S. marinus*. The differences seem to be quite clear; there is, apparently, no overlapping of the observations.

It would be of great interest to test this finding with observations from a larger material and to study this relation with respect to the "intermediate" types described by various authors, in order to determine whether this criterion is valuable in separating the two redfish forms in such populations.

4

Incidental Catches of Redfish in Cod and Haddock Surveys off the Southern Canadian Mainland during the Years 1957 to 1959

By

Y. JEAN and F. D. McCRACKEN

Fisheries Research Board of Canada, Biological Station, St. Andrews, N.B.

Introduction

During the years 1957 to 1959 bottom trawling surveys were conducted off the southern Canadian mainland (ICNAF Subarea 4) by the Fisheries Research Board of Canada Biological Station, St. Andrews, N.B. The regions surveyed, as shown in Figure 1, include the western Gulf of St. Lawrence off northern New Brunswick and Gaspé (Subdivision 4T), the waters off Cape Breton Island (Subdivision 4V and a small portion of 4T), and the Nova Scotian offshore banks (Subdivisions 4V and 4W). Hauls extending from shallow to deep water, but concentrated on top of the banks, caught mainly cod in the Gulf of St. Lawrence, off Cape Breton Island, and on the north-eastern part of Nova Scotian banks, and mainly haddock on the south-western part of these banks. These were the chief species being studied and the survey hauls caught redfish only incidentally.

This paper describes where redfish were caught, but more frequently records their absence from survey catches. It is a contribution which supplements information about the distribution of commercial redfish catches in the areas described by Martin (this volume, p. 148).

Methods

From May 1957 to June 1959 six cruises were made in Subarea 4. The dates, research vessels, size of nets, and other pertinent data for each cruise are summarized in Table 1.

A total of 700 hauls were made at about 150 stations, the locations of which are shown by circles in Figure 1. Open circles show stations where no redfish were caught and black circles stations where some were caught. No attempt has been made to plot actual numbers of redfish caught at each station, since catches made with different vessels, different sizes of nets, and different lengths of hauls are not quantitatively comparable. Instead, the importance of redfish in relation to the rest of the catch has been plotted: a small black circle where a few redfish were caught, a medium-size circle where about one-half of the catch was redfish, and a large circle where the catch was mostly redfish.

Table 1

Cod and haddock survey cruises off the southern Canadian mainland during the years 1957—1959

Date	Region	Vessel	Net size			Number of hauls	Duration of hauls in minutes
			Gross tonnage	Headrope length in feet	Cod-end		
May-Oct. 1957	Western Gulf of St. Lawrence	"J. J. Cowie"	49	37	3½ and 4 inch mesh nylon with 1½ inch mesh cover	245	45
May-Nov. 1958	Western Gulf of St. Lawrence	"J. J. Cowie"	49	37	4 inch mesh nylon with 1½ inch mesh cover	162	45
August 1958	Nova Scotian banks	"Harengus"	107	60	4½ inch mesh nylon with 1½ inch mesh cover	81	45
Feb.–Mar. 1959	Nova Scotian banks	"A. T. Cameron"	753	79	1½ inch mesh manila; no cover	128	30
May 1959	Off Cape Breton Island	"Harengus"	107	60	4½ inch mesh nylon with 1½ inch mesh cover	61	30
June 1959	Western Gulf of St. Lawrence	"Harengus"	107	60	4½ inch mesh nylon with 1½ inch mesh cover	29	30

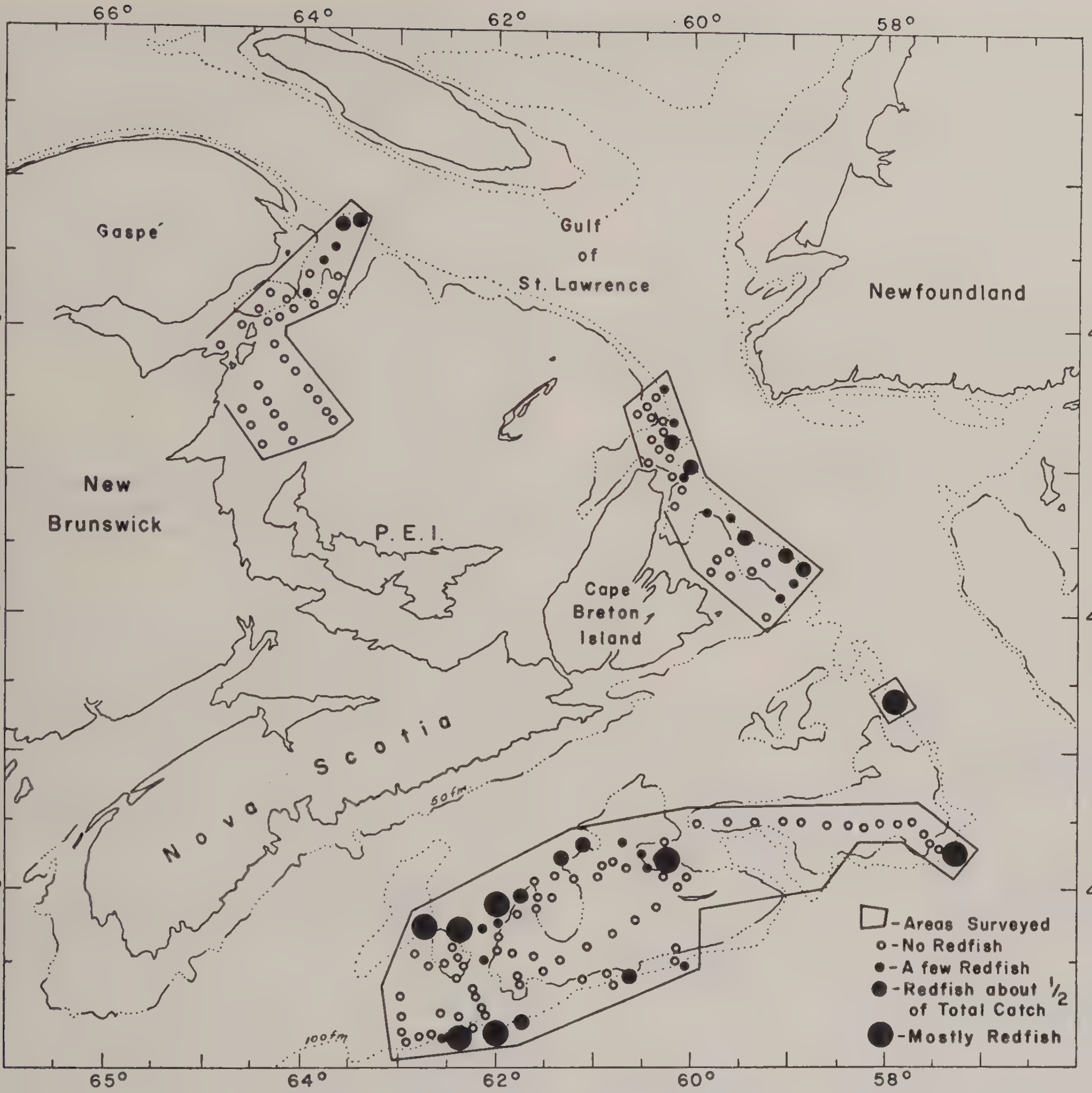
66°
64°
62°
60°
58°
48°
46°
44°
65°
64°
62°
60°
58°
Gaspe´
Gulf
of
St. Lawrence
Newfoundland
New
Brunswick
P. E. I.
Cape
Breton
Island
Nova Scotia
50fm
100fm
- Areas Surveyed
○ - No Redfish
● - A few Redfish
● - Redfish about ½ of Total Catch
● - Mostly Redfish

Figure 1. Distribution and relative abundance of redfish in areas surveyed for groundfish off the southern Canadian mainland, 1957 to 1959.

The total number of hauls per station varied from to 30, the greatest numbers being in the Gulf of St. Lawrence, where surveys have been carried out for a longer time. Off Cape Breton and on the Nova Scotian banks one or two hauls per station were usually made. Where more than one haul caught redfish at any station, the greatest catch has been plotted in Figure 1.

The presence of two types of redfish – *marinus* and *mentella* – in Canadian waters of the North-west Atlantic was first mentioned by Templeman and Sandeman (1957). In the present surveys, redfish catches were sorted into *marinus* and *mentella* types only during part of one cruise on the Nova Scotian banks (February/March 1959, Table 1). During that cruise, only one haul out of 56 caught redfish of both *marinus* and *mentella* types. In all other hauls redfish were of the *mentella* type except for a few that were recorded as "doubtful". The growth curves shown by Steele (1957) indicate that redfish caught at depths of 100 to 160 fathoms in the western Gulf of St. Lawrence in 1953 and 1954 were of the *mentella* type. For these reasons it is probable that most redfish caught in the present survey were of the *mentella* type. Templeman and Sandeman pointed out that the *mentella* type was also the dominant one in the 1956 survey catches in the south-eastern Gulf of St. Lawrence. Exploratory otter trawling in the north-eastern Gulf of St. Lawrence in 1957 caught mostly the *mentella* type (ICNAF Annu. Proc., *8*: 25, 1958).

Results

Redfish were absent from about 90 % of the survey hauls, and in all regions were absent from catches on top of the banks at depths less than 50 fathoms (Table 2 and Fig. 1). The hauls in which redfish were caught are listed in order of increasing depths in Appendix I.

Table 2
Depth distribution, by regions, of survey hauls in which redfish were caught

	Depth range in fathoms		
	12–50	51–100	101–230
	Western Gulf of St. Lawrence		
Number of hauls	304	118	14
Hauls with redfish	0	16	10
% of hauls containing redfish	0	14	71
	Off Cape Breton Island		
Number of hauls	21	32	12
Hauls with redfish	0	8	10
% of hauls containing redfish	0	25	83
	Nova Scotian banks		
	Top of banks		
Number of hauls	118	–	–
Hauls with redfish	1	–	–
% of hauls containing redfish	1	–	–
	Outer slope		
Number of hauls	–	42	13
Hauls with redfish	–	4	6
% of hauls containing redfish	–	10	46
	Inner slope		
Number of hauls	–	36	–
Hauls with redfish	–	13	–
% of hauls containing redfish	–	36	–

In the western Gulf of St. Lawrence, off the east coast of Cape Breton, and along the outer slope of the Nova Scotian banks, not more than one-quarter of the hauls between 51 and 100 fathoms caught redfish, whilst most hauls deeper than 100 fathoms did. On top of the shelf, along the inner slope of the Nova Scotian banks, redfish occurred in shallower water and were caught in one-third of the hauls between 51 and 100 fms (mainly between 55 and 75 fms, see Appendix I).

The results are consistent with the pattern of distribution of commercial redfish catches shown by Martin (this volume, p. 148). The research vessel hauls supplement the commercial catch data in showing that redfish are absent from the top of the banks where there is no commercial fishing for redfish. Both survey hauls and commercial catches show that redfish are confined to deep-water channels in the western Gulf of St. Lawrence. On Nova Scotian banks they occur at similar depths along the outer edge of the continental shelf, but also in shallower water in channels on top of the shelf.

The distribution of adult redfish is consistent with the distribution of larvae off the southern Canadian mainland. Larvae are also found mainly over the deep-water channels of the Gulf of St. Lawrence and the Nova Scotian Shelf (Dannevig, 1919; Jean, 1955; Steele, 1957; Day, this volume).

More detailed consideration of survey catches on the Nova Scotian banks (Table 3) shows that in winter the largest numbers of redfish were taken deeper than 100 fms along the outer slope of the banks. Between 51 and 100 fms in the same region, only small numbers of redfish were caught. Along the inner slope of the bank catches of intermediate numbers were made at depths of 51 to 100 fms.

Summer catches along the inner slope of the banks at depths of 51 to 100 fms were much larger than catches there in winter, even though summer fishing was carried out with a smaller vessel and smaller net (Table 1). No redfish were caught in summer at similar depths along the outer slope. Since only one haul deeper than 100 fms was made in summer, it is impossible to compare winter and summer abundance of redfish in deep water of the outer slope.

The inner and outer slopes of the Nova Scotian banks are regions of contrasting temperatures (ICNAF Annu. Proc., *7*: 27, 1957). Along the inner slope, at depths of 51 to 100 fms, where redfish were taken more frequently and in relatively large numbers, warmer water (4°–7°C) was present in both summer and winter (Table 3). On the outer slope at similar depths, where redfish were caught only occasionally and in small numbers, cold water (0°–3°C) was present in winter. In this region, warmer water (3°–4·5°C) was found only deeper than 100 fms, and redfish were most numerous there in winter.

Sizes of redfish from the Nova Scotian banks region, for a few samples taken during the winter of 1959, are presented in Appendix II. Average length of females was generally 1 to 3 cm greater than that of males from the same catch. Most redfish caught in shallow water, from 51 to 100 fms, along the inner slopes of the banks were small (about 22 cm). Those caught deeper than 100 fms on the outer slope of the banks were larger (about 37 cm). According to Schroeder (1955) still larger redfish (about 40 cm) were found in 1952/53 at depths of 220 to 370 fms along the southern slope

Table 3

Numbers of redfish in summer and winter survey hauls on the Nova Scotian banks

	Depth range in fathoms			
	51–100		101–230	
	Summer	Winter	Summer	Winter
		Outer slope		
Number of hauls	8	34	1	12
Bottom temp. range °C	7–9	0–3	9·8	3–4·5
Number of redfish in hauls ...	0	4, 97, 2, 3	3	351, 129, 472, 222, 2765
		Inner slope		
Number of hauls	5	31	–	–
Bottom temp. range °C	3·5–7·5	4·5–7·5	–	–
Number of redfish in hauls ...	14, 262, 4431, 1553, 13	196, 495, 53, 21, 15, 2, 1	–	–

of the Nova Scotian banks. The observations made during the present survey are consistent with those of Steele (1957) who showed an increase in size of redfish with increasing depth in the Gulf of St. Lawrence off Gaspé.

The larger fish caught on the outer slope of the Nova Scotian banks are comparable in size (about 37 cm) with those caught in previous surveys (Steele, 1957) in deep water off Gaspé and to those caught commercially in the Gulf of St. Lawrence (about 35 cm, Martin, this volume). Redfish caught on the inner slope of the banks are comparable in size (22 cm) to those caught commercially (25 cm) on the western Nova Scotian banks (Martin, ibid.).

Summary

Redfish were absent from about 90 % of the hauls made in groundfish surveys during the years 1957 to 1959.

No redfish were caught on top of the banks at depths shallower than 50 fms in any of the regions surveyed. Redfish were found most frequently at depths greater than 100 fms in all regions. In hauls at intermediate depths (51 to 100 fms) redfish occurred more frequently and in larger numbers on the inner slope than on the outer slope of the Nova Scotian banks. This is believed to be related to the fact that bottom temperatures are higher all the year round on the inner slope than at comparable depths on the outer slope of the banks.

The average size of redfish was larger in deep water on the outer slope than in shallow water on the inner slope of the Nova Scotian banks.

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APPENDIX I

List of bottom trawling hauls which caught redfish in ICNAF Subdivisions 4T, 4V, and 4W (in order of increasing depth)

Date	Position		Depth fms	Bottom temp. °C	Number of redfish
	Lat.	Long.			
Western Gulf of St. Lawrence					
28. May 1957	48°20′	63°52′	56	1·3	1
21. Oct. 1958	48°25′	63°46′	57	1·3	1
28. Aug. 1958	48°20′	63°52′	62	1·8	1
7. Oct. 1957	48°25′	63°46′	77	2·2	1
1. July 1958	48°41′	63°37′	77	2·6	2
7. Oct. 1957	48°25′	63°46′	79	1·9	2
3. Sept. 1958	48°41′	63°37′	82	2·4	15
3. Sept. 1958	48°41′	63°37′	82	2·4	10
22. Oct. 1958	48°41′	63°37′	84	2·4	2
22. Oct. 1958	48°41′	63°37′	84	2·4	13
4. June 1958	48°42′	63°36′	85	2·7	1
4. June 1958	48°42′	63°36′	85	2·7	8
27. Aug. 1958	48°42′	63°36′	86	3·8	50
27. Aug. 1957	48°42′	63°36′	87	3·9	25
8. Oct. 1957	48°42′	63°37′	89	3·0	10
8. Oct. 1957	48°42′	63°37′	90	3·4	27
26. June 1957	48°48′	63°36′	110	3·1	a few
21. Nov. 1958	48°48′	63°36′	110	3·0	abt. 45
30. May 1957	48°48′	63°36′	112	3·9	6
30. May 1957	48°48′	63°36′	114	4·0	21
21. Nov. 1958	48°48′	63°35′	115	3·0	abt. 50
27. Aug. 1957	48°48′	63°35′	119	5·3	a few
9. Oct. 1957	48°49′	63°36′	120	4·4	173
21. May 1958	48°49′	63°36′	120	4·0	20
27. Aug. 1957	48°49′	63°36′	121	5·0	a few
30. May 1957	48°53′	63°30′	150	–	7
Off Cape Breton Island					
7. May 1959	46°09′	59°04′	52	0·6	1
7. May 1959	46°14′	58°58′	77	2·8	4
7. May 1959	46°14′	58°58′	77	2·8	1
13. May 1959	46°52′	60°03′	86	3·0	6
15. May 1959	47°02′	60°10′	91	4·4	9
7. May 1959	46°18′	58°58′	94	3·8	280
7. May 1959	46°48′	59°45′	96	3·4	75
7. May 1959	46°27′	59°14′	100	3·0	244
7. May 1959	46°27′	59°14′	103	3·0	75
13. May 1959	46°48′	59°45′	104	3·4	10
21. May 1959	47°28′	60°22′	105	–	1
20. May 1959	47°16′	60°21′	108	4·9	16
22. May 1959	47°40′	60°32′	111	3·5	10
15. May 1959	47°04′	60°09′	113	4·8	4
15. May 1959	47°04′	60°09′	113	4·8	150
20. May 1959	47°16′	60°21′	113	4·9	18
13. May 1959	46°53′	59°53′	117	4·2	40
16. May 1959	47°16′	60°19′	124	4·5	120
Nova Scotian banks					
16. Mar. 1959	44°21′	60°52′	50	–	2
22. Mar. 1959	43°30′	62°04′	54	–	2
26. Feb. 1959	44°13′	61°19′	57	6·5	495
17. Mar. 1959	43°24′	60°30′	60	–	97
13. Aug. 1958	43°50′	61°53′	63	6·8	1553
27. Feb. 1959	43°52′	61°59′	63	7·0	21
18. Mar. 1959	44°20′	60°35′	64	–	1
26. Feb. 1959	44°22′	61°08′	65	4·4	196
17. Mar. 1959	43°25′	60°19′	65	–	2
27. Feb. 1959	43°50′	62°12′	70	7·4	15
13. Aug. 1958	43°44′	62°14′	71	7·2	13
13. Aug. 1958	43°44′	62°14′	71	7·2	4431
27. Feb. 1959	43°57′	61°59′	72	6·9	53
16. Aug. 1958	44°15′	60°20′	73	3·8	262
1. Mar. 1959	42°52′	62°36′	74	2·8	4
15. Mar. 1959	44°13′	60°28′	82	–	25
9. Sept. 1958	43°49′	62°32′	96	7·4	14
19. Aug. 1958	42°58′	61°56′	103	9·8	3
26. Mar. 1959	43°53′	62°42′	114	–	3
22. Feb. 1959	45°21′	57°34′	120	4·4	351
24. Feb. 1959	44°22′	57°21′	125	3·0	472
28. Feb. 1959	42°55′	62°05′	138	3·1	2765
28. Feb. 1959	42°58′	62°27′	210	3·4	222
22. Feb. 1959	45°22′	57°34′	230	4·4	129

APPENDIX II

Size compositions of redfish caught in the Nova Scotian banks region in February—March 1959

Region	*Outer Slope*										*Inner Slope*					
Latitude	45°21′		44°22′		42°55′		42°58′		45°22′		43°57′		44°13′		44°22′	
Longitude	57°34′		57°21′		62°05′		62°27′		57°34′		61°51′		61°19′		61°08′	
Depth in fathoms	120		125		138		210		230		57		57		65	
Length, cm	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀
5	–	–	–	–	–	–	–	–	–	–	–	–	3	–	–	–
6	–	–	–	–	–	–	–	–	–	–	–	–	3	–	–	–
7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
8	–	–	–	–	–	–	–	–	–	–	–	–	3	–	–	–
9	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–
10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
11	–	–	–	1	1	–	–	–	–	–	1	–	6	3	–	–
12	–	–	–	–	3	2	–	–	–	–	–	1	6	3	–	–
13	–	–	–	–	3	–	–	–	–	–	1	1	6	–	–	–
14	–	–	1	–	7	12	–	–	–	–	2	–	6	–	–	–
15	–	–	–	–	16	6	–	–	–	–	2	–	–	6	–	–
16	–	–	–	3	17	12	–	–	–	–	1	1	3	–	3	2
17	–	–	1	5	21	9	–	–	–	–	–	4	9	9	8	–
18	–	–	–	3	29	17	–	–	–	–	2	3	21	9	9	3
19	–	–	–	1	34	27	–	–	–	–	3	1	42	27	12	5
20	–	–	–	5	30	26	–	–	–	–	1	3	33	30	13	9
21	–	–	8	8	20	19	–	–	–	–	3	2	57	33	10	5
22	–	–	8	22	25	19	–	1	–	–	3	1	39	39	12	5
23	–	–	17	27	36	11	1	–	–	–	5	–	24	15	15	4
24	–	–	23	29	32	17	2	–	–	–	2	–	18	3	7	6
25	–	–	32	29	30	13	3	2	–	–	1	2	12	3	13	8
26	–	–	39	16	17	12	4	4	–	–	–	1	6	6	6	6
27	–	–	19	19	9	7	9	1	–	–	–	5	–	6	4	11
28	–	–	13	19	5	–	5	1	–	–	–	1	–	3	3	5
29	–	–	7	18	7	–	8	2	–	–	–	–	–	–	1	4
30	–	1	4	5	–	–	5	4	–	1	–	–	–	–	–	4
31	5	–	4	–	1	–	1	4	1	–	–	–	–	–	–	2
32	7	1	1	–	–	–	3	1	2	–	–	–	–	–	–	–
33	24	6	2	–	–	–	2	1	11	3	–	–	–	–	–	1
34	34	10	1	1	–	–	2	1	15	1	–	–	–	–	–	–
35	48	12	1	–	–	–	–	2	23	2	–	–	–	–	–	–
36	38	16	–	–	–	–	–	1	21	4	–	–	–	–	–	–
37	22	14	–	–	–	–	–	3	12	2	–	–	–	–	–	–
38	17	15	–	–	–	–	–	1	2	2	–	–	–	–	–	–
39	15	12	–	–	–	–	–	–	2	2	–	–	–	–	–	–
40	7	12	–	–	–	–	–	–	3	5	–	–	–	–	–	–
41	5	10	–	–	–	–	–	–	3	–	–	–	–	–	–	–
42	2	4	–	–	–	–	–	–	1	4	–	–	–	–	–	–
43	3	–	–	–	–	–	–	–	–	4	–	–	–	–	–	–
44	–	2	–	–	–	–	–	–	1	1	–	–	–	–	–	–
45	–	2	–	–	–	–	–	–	–	1	–	–	–	–	–	–
46	–	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–
>46	–	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Total.........	227	123	181	211	344	209	45	29	97	32	27	26	297	195	116	80
Av. length in cm......	36	38	26	24	21	20	29	31	36	39	20	21	20	21	22	24

5.

The Distribution of Redfish Catches landed on the Southern Canadian Mainland, 1949—1958

By
W. R. MARTIN
Fisheries Research Board of Canada, Biological Station, St. Andrews, N. B.

Introduction

Annual landings of redfish (*Sebastes marinus* L.) on the southern Canadian mainland (Maritimes and Quebec) increased from 2 million lbs in 1949 to 35 million lbs in 1958. Data on area fished and fishing effort, collected from captains of commercial draggers landing these catches, are summarized below.

Canadian research vessel studies of redfish in ICNAF Subarea 4 are reported by Steele (1957), Templeman (1959), and by Jean and McCracken (this volume). In these papers distribution is described by depths, sizes, and sexes for limited survey areas. The present paper extends these observations by describing the distribution and sizes of redfish as they have been found in commercial concentrations by otter trawlers based at ports from Lunenburg to Louisburg in Nova Scotia, and from Shippegan, New Brunswick, to Fox River on the Gaspé coast of Quebec.

The locations of fishing ports and fishing grounds considered in this paper are shown in Figure 1.

Table 1
Redfish landings by months for the years 1952 to 1958 in Canada (excluding Newfoundland) in thousands of pounds round fresh weight

Month Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Total
1952	562	364	55	2	236	529	1,773	988	485	1,367	931	639	7,931
1953	602	342	437	148	606	2,441	2,642	4,655	4,112	964	529	631	18,109
1954	937	344	326	426	1,345	5,165	6,484	6,746	4,021	2,963	655	104	29,516
1955	315	337	220	494	827	2,487	2,758	7,522	4,630	3,680	1,570	414	25,254
1956	66	84	251	71	677	6,409	7,310	6,060	6,298	5,276	1,726	586	34,814
1957	32	125	39	102	361	4,013	6,539	6,532	4,102	4,033	1,962	1,509	29,349
1958	660	367	295	79	1,524	4,810	8,358	7,123	4,301	4,475	2,510	1,035	35,537
Totals	3,174	1,963	1,623	1,322	5,576	25,854	35,864	39,626	27,949	22,758	9,883	4,918	180,510
% by months ..	2	1	1	1	3	14	20	22	15	13	5	3	

Season

Landings for the years 1952 to 1958 are presented by months in Table 1. Most of the landings (84 %) were made in the months of June to October, and half of these (42 % of total) in July and August. Redfish dragging in the important Gulf of St. Lawrence area has been restricted from November to May by winter weather and ice conditions, and by conversion to more profitable cod and haddock dragging in the spring months, when these species are concentrated on Nova Scotian banks.

Since most redfish are caught in the summer months, no attempt has been made to describe seasonal variations in the distribution of catches.

Areas

The changing distribution of redfish catches is shown, for representative years, in Figure 2. As the Canadian mainland fishery has grown, otter trawlers have shifted to more distant grounds. In 1949 the redfish catch of 2 million lbs was mainly taken off the Nova Scotian coast. By 1951 part of the catch was taken from Grand Bank, and in 1952 over half the catch of 8 million lbs came from the southern edge of the Grand Bank, with the remainder mainly from the Laurentian Channel. In 1953 the annual catch increased to 18 million lbs, and the Esquiman Channel in the Gulf of St. Lawrence became the major fishing ground. The Mingan Channel in the Gulf of St. Lawrence was

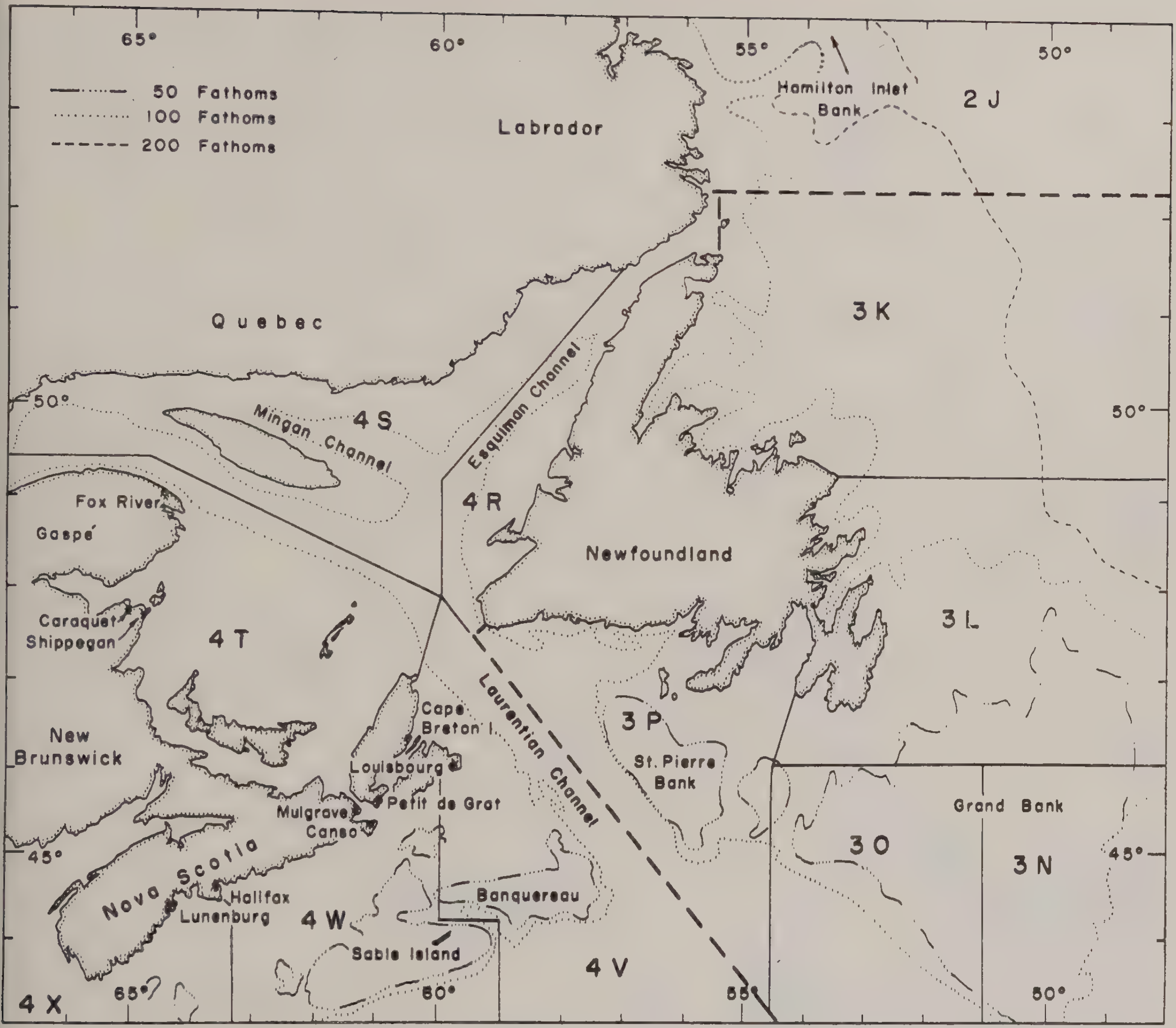
65°
60°
55°
50°
50 Fathoms
100 Fathoms
200 Fathoms
Labrador
Hamilton Inlet Bank
2 J
3 K
Quebec
50°
4 S
Mingan Channel
Esquiman Channel
4 R
Fox River
Gaspé
Newfoundland
3 L
Caraquet
Shippegan
4 T
Laurentian Channel
New Brunswick
Cape Breton I.
3 P
St. Pierre Bank
Louisbourg
Petit de Grat
Mulgrave
Canso
Grand Bank
45°
Nova Scotia
Halifax
Lunenburg
4 W
Banquereau
3 O
3 N
Sable Island
4 V
4 X
65°
60°
55°
50°
45°

Figure 1. Ports and fishing areas occupied by Canadian mainland redfish trawlers, 1949–1958.

Table 2

Catch in relation to hours dragged by Canadian mainland otter trawlers (100 to 350 gross tons) in thousands of lbs round fresh weight

ear	Nova Scotian Banks Subdivisions 4X–4W–4V			St. Pierre and Grand Banks Subarea 3			Gulf of St. Lawrence Subdivisions 4T–4R–4S			Labrador Hamilton Inlet area 2J		
	Wt	Hrs	C/P/H	Wt	Hrs	C/P/H	Wt	Hrs	C/P/H	Wt	Hrs	C/P/H
949	862	383	2·3	–	–	–	–	–	–	–	–	–
950	65	28	2·3	–	–	–	–	–	–	–	–	–
951	95	96	1·0	1,856	377	4.9	–	–	–	–	–	–
952	74	57	1·3	1,057	377	2·8	580	393	1·5	–	–	–
953	306	208	1·5	1,501	539	2·8	10,214	4,537	2·3	–	–	–
954	609	336	1·8	1,146	529	2·2	20,305	8,710	2·3	–	–	–
955	67	48	1·4	393	195	2·0	19,335	8,277	2·3	–	–	–
956	42	22	1·9	550	209	2·6	27,778	15,492	1·8	–	–	–
957	12	15	0·8	126	103	1·2	22,396	15,132	1·5	–	–	–
958	815	644	1·3	147	128	1·1	16,285	13,141	1·2	6,341	2,520	2·5

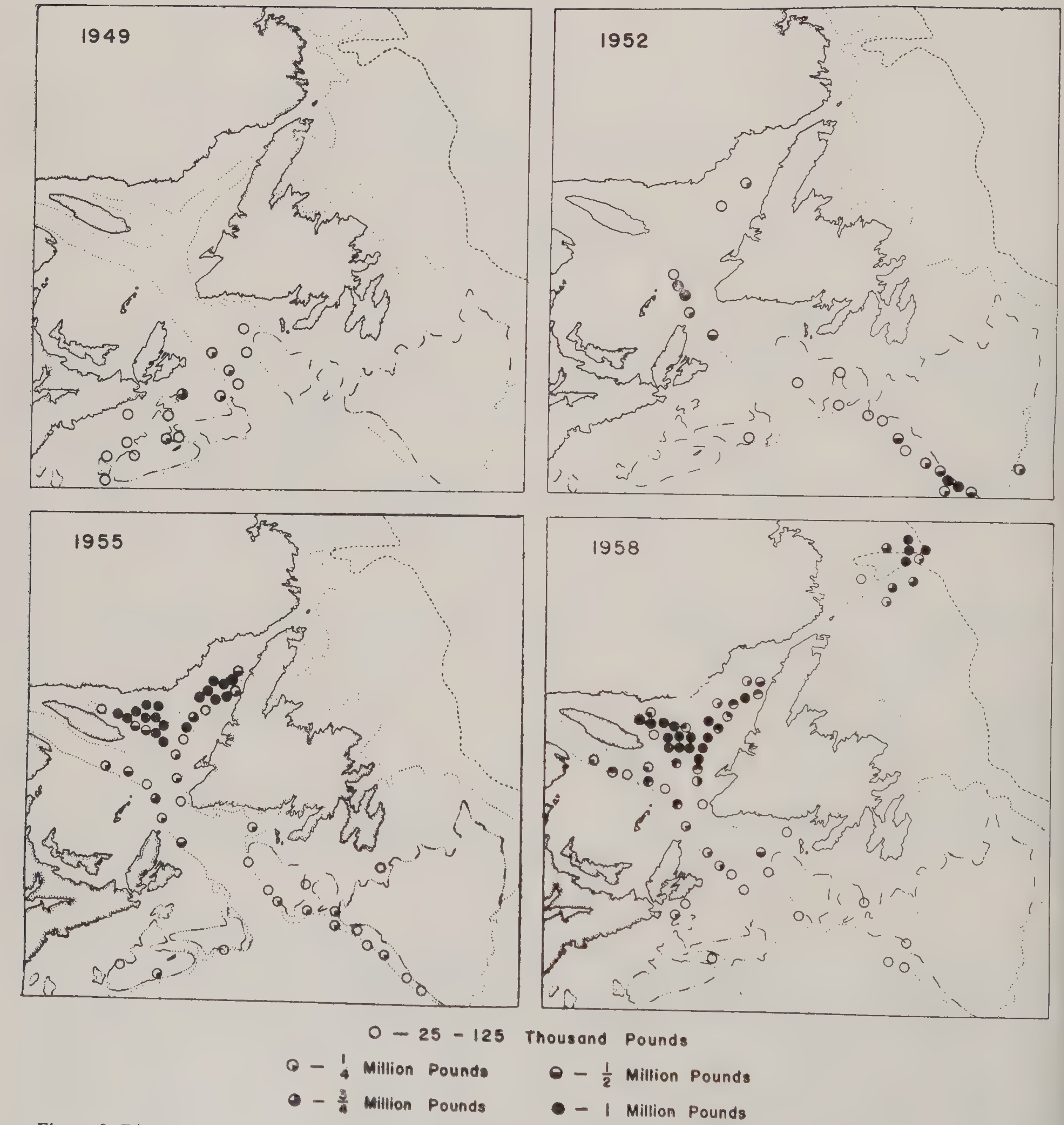
1949
1952
1955
1958
○ — 25 - 125 Thousand Pounds
◔ — 1/4 Million Pounds
◑ — 1/2 Million Pounds
◕ — 3/4 Million Pounds
● — 1 Million Pounds

Figure 2. Distribution of commercial redfish catches which were landed on the southern Canadian mainland during the years 1949, 1952, 1955, and 1958.

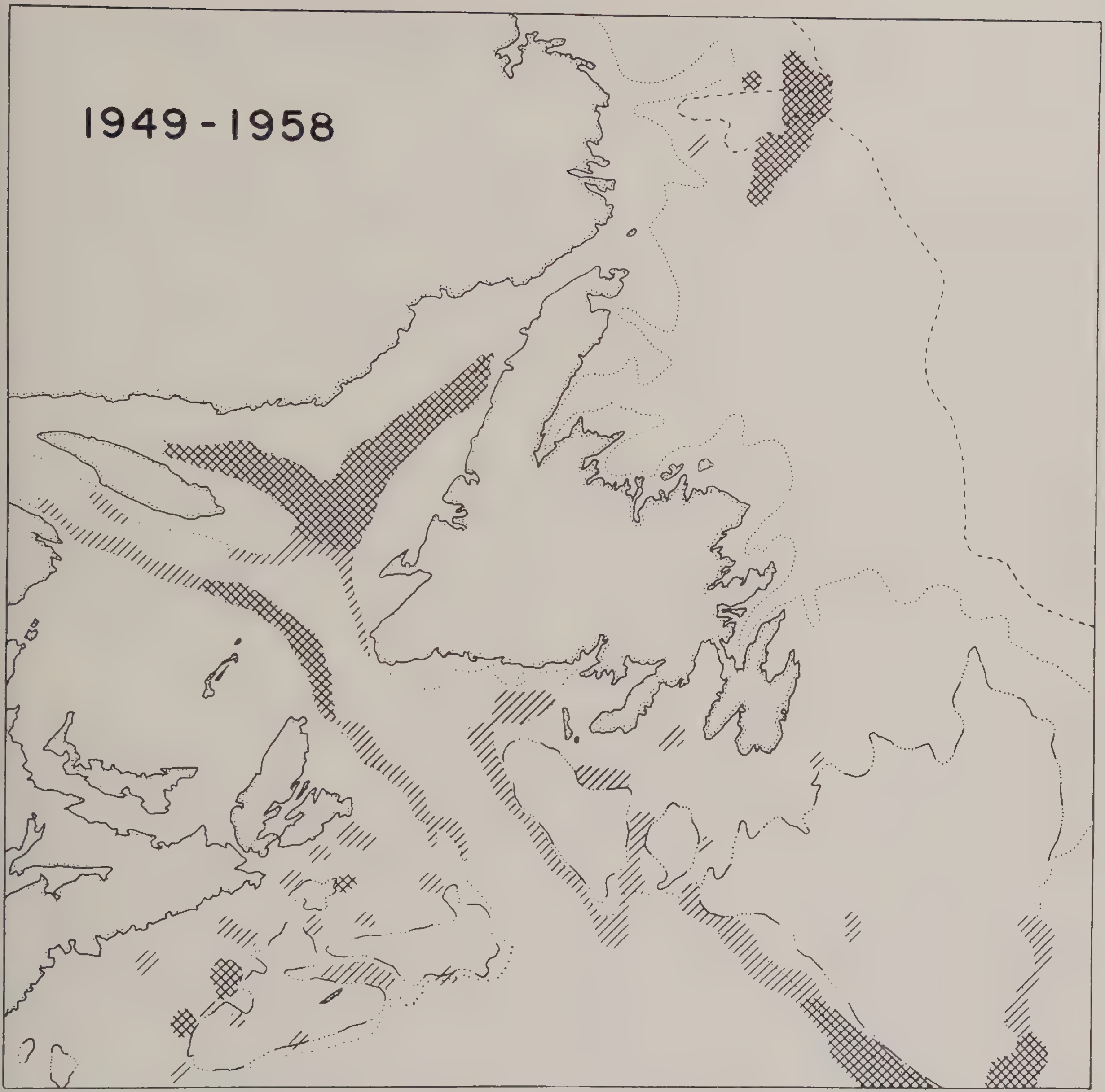

Figure 3. Distribution of redfish catches which were landed by Canadian mainland trawlers during the years 1949 to 1958 inclusive. The largest catches are shown as cross hatching.

the important fishing area in 1954. The 1955 catch of 22 million lbs was largely taken from the deep channels of the north-eastern Gulf of St. Lawrence, and they continued to be the principal redfish fishing grounds through 1958. In 1958 about 7 million lbs of redfish were caught in the Hamilton Inlet Bank area off Labrador, and the total Canadian mainland landings reached 35 million lbs.

A composite map of the distribution of redfish catches landed in Canada (excluding Newfoundland) during the years 1949 to 1958 is presented as Figure 3. It is apparent that commercial catches of redfish have been taken at one time or another all along the 100 fathom contour, throughout the area fished. This distribution of catches for a 10-year period gives a clearer picture than that presented in Figure 2, of the

Table 3. Redfish length frequencies as landed at Nova Scotian ports, by ICNAF subdivisions, in %

	4X		4W	3O	3P	4V			4T					4R					4S				
Date	Nov.	Nov.	Feb.	Sept.	June	Apr.	May	May	June	June	June	Sept.	Sept.	Aug.	Oct.	Nov.	July	Sept.	Sept.	Oct.	Oct.	Nov.	July
Length cm	1949		1949	1952	1948	1953	1956		1956			1955			1956				1956				1957
20	–	–	1	0·5	1	–	–	–	–	–	–	–	–	–	–	–	–	–	0·5	–	–	–	–
21	1	3	12	0·5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
22	5	12	9	0·5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
23	19	15	8	1	–	–	2	2	–	–	1	–	–	1	–	–	–	1	–	0·25	–	–	–
24	19	18	12	4·5	1	0·5	–	–	–	1	–	–	–	–	–	–	0·5	0·5	–	0·5	–	–	–
25	11	14	11	6·5	1	1	–	–	–	1	–	–	–	–	0·5	–	0·5	–	0·5	0·5	–	2	0·5
26	13	13	8	5·5	3	1	2	5	–	–	4	–	–	–	0·5	–	1	0·5	–	0·25	1	2	1
27	13	10	9	7·5	4	2	7	3	1	1	4	1	–	1	1	–	1	0·5	1	0·25	–	1	1
28	8	4	8	14	7	4·5	8	11	1	1	3	3·5	1	1	1·5	–	0·5	–	0·5	–	1	–	1
29	3	8	7	7·5	9	12·5	11	7	5	1	1	5·5	3·5	2	1·5	–	2·5	2	3	0·5	2	–	2
30	3	2	10	11	25	10	3	4	4	4	1	1	2	4	15	4	11	1	3·5	4	3	7	10·5
31	5	1	4	5·5	2	14·5	7	13	3	3	4	3	–	4	13·5	2	5·5	4	4·5	2	3	1	12·5
32	–	–	1	8·5	11	7	8	9	3	1	3	3·5	6	2	19·5	3	15	7·5	8	3·5	2	4	13·5
33	–	–	–	9·5	7	10	6	6	5	3	3	4	5·5	10	10·5	9	3·5	8·5	6·5	5·75	8	2	13
34	–	–	–	7	9	11	4	5	6	8	8	5	12·5	14	7	4	7·5	12	9·5	5·75	9	5	12
35	–	–	–	3	5	12	11	8	9	14	14	11·5	13	12	5	6	6	11·5	10	8·25	9	8	12·5
36	–	–	–	5·5	5	7·5	13	5	18	13	10	9	14	8	3·5	12	12	10·5	7	7·25	6	12	4·5
37	–	–	–	1·5	5	5·5	5	10	17	13	15	7·5	12·5	9	4·5	13	7	8	9·5	8	10	18	5·5
38	–	–	–	0·5	1	0·5	7	1	9	13	5	11·5	12	13	5	17	8	10	9·5	8·75	20	13	4
39	–	–	–	–	1	–	2	4	9	11	13	11	7·5	6	6	11	8	9	12·5	17	5	5	2·5
40	–	–	–	–	2	–	3	5	3	4	6	12	5	9	3	11	4·5	8	7·5	15	13	8	3·5
41	–	–	–	–	1	–	1	2	3	4	2	6	4	1	2	4	3	4·5	3·5	5·5	5	5	–
42	–	–	–	–	–	–	–	–	3	1	–	5	1	2	0·5	2	1·5	0·5	2·5	4	1	2	0·5
43	–	–	–	–	–	–	–	–	1	2	3	–	–	1	–	2	1·5	–	–	3	2	4	–
44	–	–	–	–	–	0·5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
45	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	1	–
n	100	100	100	200	100	200	100	100	100	100	100	200	200	100	200	100	200	200	200	400	100	100	200
Mean cm	25·4	26·0	25·5	29·8	31·5	32·2	32·7	32·5	35·7	36·1	35·2	36·3	35·2	35·5	33·3	36·8	34·6	35·4	35·5	37·0	36·4	36·4	33·4

continuous distribution of redfish along the edge of the continental shelf and in the deep-water channels on the shelf.

Depth

As the redfish fishery shifted to more distant grounds, the depth fished has increased. In 1949 redfish draggers fished from 60 to 100 fathoms on Nova Scotian banks. They fished down to 180 fms on the edges of St. Pierre and Grand Banks, to 200 fms in the Gulf of St. Lawrence, and as deep as 220 fms south and east of Hamilton Inlet Bank. Although redfish have been taken over a large area and a wide range of depths, most redfish catches have been taken from the Gulf of St. Lawrence, between the 100 and 180 fathom contours.

Abundance

The extension of fishing grounds to new areas has been related, in part, to decreasing abundance of redfish. A summary of data on catch per hour is presented in Table 2 (p. 149) for the major fishing areas. In each area the availability of redfish has decreased with time. During early years of exploitation of each area, catch per hour dragged exceeded 2,000 lbs, but as fishing continued catch per hour dragged dropped to about 1,000 lbs. When catch per hour dragged decreased, otter trawlers moved to more distant but more lucrative grounds.

Sizes

The shift of commercial redfish dragging to areas more distant from Nova Scotia has also been related to the size composition of the fish. Occasional samples of the length frequency of commercial landings of redfish are summarized in Table 3. Redfish landed from western Nova Scotian banks (4X and W) have been small, with a mean length of about 25 cm. Redfish from Grand Bank (3O) had a mean length of about 30 cm and a mean weight of about one pound. Samples of redfish landings from the Cape Breton area (4V) and the St. Pierre Bank area (3P) had mean lengths of about 32 cm. Those from the Gulf of St. Lawrence (4R, S, and T) had mean lengths of about 35 cm (approximately 1½ pounds). Finally, although samples were not taken, it was reported by field technicians that redfish from the Hamilton Inlet area (2J) were the largest of all, with many large *marinus*-type redfish in the catches.

Summary

1. Commercial landings of redfish on the southern Canadian mainland have increased from 2 million lbs in 1949 to 35 million lbs in 1958.

2. Most redfish have been caught in a 5-month season, June to October. In the period 1952 to 1958 only 16 % were landed from November to May.

3. Fishing grounds have been extended from Nova Scotian banks in 1949 to the southern tip of the Grand Bank in 1951, to the Laurentian Channel in 1952, to Esquiman Channel in 1953, to Mingan Channel in 1954, and finally to an area south-east of Hamilton Inlet Bank in 1958. To date, the most important fishing grounds have been in the north-eastern Gulf of St. Lawrence.

4. Commercial catches of redfish have been taken all along the 100 fathom isobath from Nova Scotian and Newfoundland banks, through the Gulf of St. Lawrence, to Hamilton Inlet Bank off Labrador. The distribution of redfish is continuous.

5. As fishing has shifted to more distant grounds, the depth fished has increased. Most fishing on Nova Scotian banks has been shoaler than 100 fms. On Newfoundland banks and in the Gulf of St. Lawrence most redfish dragging has been from 100 to 180 fms. Recent fishing near Hamilton Inlet Bank has been still deeper, down to 220 fms.

6. The abundance of redfish, as measured by catch per hour dragged, has decreased with continued exploitation in each of the major redfish areas fished by Canadian mainland otter trawlers. When abundance dropped on local grounds, fishing operations shifted to more distant and more lucrative fishing grounds.

7. The extension of commercial operations to more distant grounds has also been related to the progressively larger sizes of redfish taken by otter trawlers as they have moved north through the Gulf of St. Lawrence to Hamilton Inlet Bank.

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6.

Redfish Distribution in the North Atlantic*

By

WILFRED TEMPLEMAN

Fisheries Research Board of Canada, Biological Station, St. John's, Newfoundland

Abstract

The distribution of *Sebastes marinus* and to a much lesser degree that of *Sebastes viviparus* are described. Although *Sebastes marinus* may be divided into *Sebastes marinus marinus,* the ordinary redfish, and *Sebastes marinus mentella,* the deep-water redfish, these two subspecies have not, as a rule, been differentiated in the available statistical and other data. Therefore, with regard to most of the information, it is possible to consider only the distribution of *Sebastes marinus* including both subspecies. The name redfish in this abstract refers to *Sebastes marinus.*

Sebastes viviparus is well differentiated from *S. marinus* by the greater number of scale rows in the latter. *S. marinus mentella* has a sharply projecting beak on the lower jaw and a large eye whereas in *S. marinus marinus* this beak is absent, or present as a rounded protuberance, and the eye is relatively small.

In *S. viviparus* the most anterior preopercular spine is directed backward. In *S. marinus marinus* of the Newfoundland area it is usually directed downward or obliquely downward and backward. In *S. marinus mentella* of the Newfoundland area this anterior preopercular spine is usually directed obliquely downward and forward.

Redfish larvae and young have been found abundantly in the Norwegian Sea, west and south of Iceland (including a great oceanic area south of Iceland and extending almost to Flemish Cap), in southern Greenland waters, and in the Newfoundland, Grand Bank, Gulf of St. Lawrence, Nova Scotian, and Gulf of Maine areas. Larval redfish tend to be most numerous above the deeper water bank and channel contours where adult redfish are abundant; they have a pelagic life of at least several months in the upper water layers. Although in northern Greenland waters young redfish up to 45 to 50 mm are numerous in these upper water layers, in the region from Newfoundland to the Gulf of Maine, redfish of 30 mm and over are not commonly caught near the surface in plankton nets but rather in bottom trawls. Some redfish of these sizes have recently been captured, however, in mid-water in the Gulf of Maine by means of a mid-water trawl.

The redfish fishery in the ICNAF area, which began as a special fishery in the Gulf of Maine in 1935, is now carried out in all ICNAF subareas. The greatest catch was 159,000 metric tons in 1957. In the latter year the United States catch was 61,000 metric tons; followed by the USSR, 49,000; Canada, 21,000; Germany, 15,000; and Iceland, 13,000. Almost half the catch was obtained in Subarea 3 of ICNAF (the Newfoundland subarea). The total redfish catch by the European countries of the International Council for the Exploration of the Sea (ICES) and the USSR increased gradually (with some downward variations during wars) from 1,000 metric tons in 1907 to 294,000 in 1955, falling again to 251,000 in 1956. As a rule, before 1955 over half of the catch came from the Icelandic grounds, with, until 1954, the Barents Sea, Bear Island, and Spitsbergen area usually next in importance. In 1954 the redfish catch in Greenland increased beyond that in the Barents Sea, Bear Island, and Spitsbergen area, and in 1955 the catch from Greenland was slightly greater than that from the Icelandic area. In 1956 landings from the Greenland area again fell considerably below those from the Icelandic area. In 1956, 50 % of the redfish was caught by Germany, 27 % by Iceland, and 17 % by the USSR. The redfish catch in the West Greenland Subarea (1) of ICNAF amounted to 14,000, 16,000, 32,000, and 14,000 metric tons in the years from 1953 to 1956 respectively, and less than 1,000 in earlier years, and is included both with the ICNAF and the ICES catches; otherwise the ICES and USSR catches up to and including 1955 were from east of the ICNAF area. In 1956 the ICES landings include 13,000 metric tons taken in the Newfoundland subarea almost entirely by the USSR.

Explorations by the research vessel "Investigator II" of the Fisheries Research Board of Canada's Station at

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St. John's from 1947 to 1954, and the commercial fishing largely resulting from these otter-trawling explorations, have shown redfish in the various deep channels of the Gulf of St. Lawrence and in deep water around the fringes of the banks in the Newfoundland and Labrador area, as far northward as off the northern tip of Labrador. Commercial fishing possibilities exist at least as far north as east of Hamilton Inlet Bank and as far east as Flemish Cap.

Sebastes viviparus lives in considerably shallower water than *Sebastes marinus*. It occurs in numbers from the Finnmark coast of Norway southward along the Norwegian coast, in the northern North Sea, off Scotland, Ireland, northern England, the Faroes, and south and west of Iceland.

Sebastes marinus is common in the Barents Sea to Spitsbergen, along the Norwegian coast to the Faroes, Iceland, southern Greenland, Labrador, Flemish Cap, the Grand Bank, the Gulf of St. Lawrence, and southward to the Gulf of Maine. Individual captures are reported to the north-east off West Spitsbergen at Lat. 80°06′N and Long. 11°17′E, off West Greenland north to Umanak Fjord in about Lat. 71°N, and the most southerly record along the American continent is at Lat. 39°48′10″N, and Long. 71°48′40″W.

Sebastes marinus mentella is distributed in the deep water from south of Bear Island to West Greenland. It is the common form throughout the Labrador, Newfoundland, and probably the whole North American area. *Sebastes marinus marinus* is abundant in the shallower parts of the deep-water area from the Barents Sea and the Bear Island grounds to West Greenland. It is moderately abundant in limited portions only of the Newfoundland-Labrador area, but here also it occurs in shallower water than the deep-water *mentella* form. Bottom temperatures and depths suited to the *mentella* form are continuous over the whole redfish range from Georges Bank to the most north-easterly part of its distribution off the Russian coast. The bottom connection between West Greenland and Baffin Island and also the bottom areas in some of the channels to the east are suited in depth only to the *mentella* form. Populations of the *marinus* form may be connected only pelagically, across these channels.

The *marinus* type and probably also *mentella* are plentiful off West Greenland, and both are abundant off East Greenland. On the basis of the available imperfect data, although *mentella* is present, *marinus* is the common form on the Norwegian grounds and in the Barents Sea. *Marinus* is present in the shallower and *mentella* in the deeper water near Iceland, whereas *mentella* is the common form on the Iceland-Faroe Ridge and on the Bear Island deep-water grounds. It must be remembered, for the European area, that *marinus* lives shallower, is larger and is more favoured in the market, and thus when in equal or in slightly lesser abundance will usually be fished for instead of *mentella*. Most of the redfish landed in Iceland and Europe, at least until recent years, have been of the *marinus* type.

The pelagic existence of numerous redfish, over water much too deep for them to descend to the bottom, has been demonstrated for the Norwegian Sea. The presence of great quantities of redfish larvae over a wide area south of Iceland, in the absence of another explanation, makes it plausible to believe that a large pelagic population of redfish may be present in this area, but this belief cannot in any way be regarded as proven. In the area from west of the tail of the Grand Bank southward to Cape Cod, there are no extensive areas, at suitable redfish depths seaward of the bank slopes, with temperatures suitably low for redfish. It is thus extremely unlikely that large pelagic populations of redfish exist seaward of the bank slopes in the southern part of the North-west Atlantic.

In comparisons of redfish catches by Newfoundland otter trawlers over the 24-hour period, sets carried out more than an hour before sunrise or after sunset usually had negligible redfish catches compared with the daylight period. However, in some deep-water areas where redfish were abundant, night sets, although considerably smaller than daylight sets, were large enough to make night fishing worth while. Although more data are desirable, there was a tendency in the 50 to 75 fathom depths, and in the May to July catches at most depths, to have morning and afternoon peaks in the catch. Between 76 and 160 fathoms the morning catches were usually greater than the afternoon catches. In the darkest months, November to January, the largest catches in the deeper water were in the late morning or at noon. In the deepest water, 161 to 190 fathoms, the highest catches were from late morning to the earlier part of the afternoon. Good catches extended over a longer part of the day in the brightest months with the longest period of daylight, May to July.

In the Newfoundland redfish catches from January to April mature females were much less abundant than large males. In May and June mature females were scarce at the shallower depths but plentiful in greater depths. In July and August and in November and December females were more numerous than males. During September and October mature females were scarce at intermediate depths. Corresponding to the lack of availability of mature females, the catch of redfish per hour's dragging was at a minimum in March. In Hermitage Bay, in catches between April and December, mature females were considerably fewer than large males. In April, in fish of mature size 30 cm and over, females formed only 9 % of the catch.

European, Icelandic, and Greenland commercial redfish are usually larger than those of North America. Redfish from the deep water off Labrador are also large. Close analysis is impossible since usually the *marinus* and *mentella* forms have not been separated in the length-frequencies, but differences in the size at sexual maturity and in temperature and other environmental factors in these areas, with resulting growth differences, are doubtless factors of importance in determining the limits of redfish size.

At depths between 51 and 210 fathoms in the various divisions of the Newfoundland area, greatest redfish catches were obtained in the 131 to 210 fathom range. Most large catches occurred at depths where average temperatures were between 3·4 and 5·0°C, but on the eastern slope of the Grand Bank the greatest catches were at a depth where the average temperature was 2·1°C. When catches at individual depths are considered the larger catches were usually between 1° and 5°C. The tendency to obtain large catches at these moderately low temperatures was particularly evident at the greater depths whereas at the lesser depths (51 to 90 fathoms) where redfish are smaller and fewer the best catch averages were at 5° to 6°C. In the Newfoundland-Labrador region large populations of redfish exist only in or near areas where temperatures at redfish depths are over 3°C.

In many parts of the bank slopes of the North-west Atlantic from Georges Bank to southern Labrador, redfish investigations in deep water during recent years have demonstrated abundant redfish beyond the 200 fathom depth which until recently was the usual commercial fishing limit. These redfish, usually larger than those of the same subspecies (*mentella*) from shallower water, occur in apparent commercial abundance often to 250 fathoms, sometimes at 300 and occasionally at 350 fathoms. Individual redfish have been captured at 451 to 500 fathoms.

The data available agree with Tåning's conclusion that redfish are not plentiful except in areas where temperatures between 3° to 8°C exist in depths of about 200 to 500 metres (110 to 270 fms). Over most of the North-west Atlantic the temperatures at these depths in areas of redfish abundance are usually between 3° and 6°C. In the Icelandic area redfish are abundant mainly in the warmer water to the south and west and are usually scarce in the colder water to the north and east. The decreasing quantities of redfish, found in proceeding southward on the seaward slope of Georges Bank, may be explained by the increasingly high temperatures in redfish depths, and the existence of a large population of redfish in the Gulf of Maine is correlated with moderately low sea temperatures over most of the year. Both on the southern Nova Scotian Shelf area and in the Gulf of Maine the greatest amount of redfish is coastward where the lowest temperatures are to be found, or in deep water on the seaward edge of the slope where deep-water temperatures are lower than those in the shallower water.

Within the temperature range suited to redfish, depth is more important than temperature in the vertical distribution of the *marinus* and the *mentella* types of redfish. In the European area *mentella* lives in colder water than *marinus,* but in the North-west Atlantic *marinus* usually lives in colder water than *mentella.* In the Flemish Cap area both forms live in water of the same temperature. In all three areas *mentella* is in the deeper and *marinus* in the shallower water and the depth relationships of the two forms are approximately the same in all three areas.

Many factors may be responsible for local concentrations of a redfish population. Among these factors are light, food, spawning cycle, temperature, bank slopes and ridges, depressions in the continental shelf, stranding by currents, V-shaped areas, under-water projections of banks, and type of bottom.

The abundance of the *marinus* type in the European area coincides with the presence of a thick upper layer of moderately warm North Atlantic Current water, whereas this shallower water form is relatively scarce in the North-west Atlantic, where the water at the levels inhabited by *marinus* is typically cold. The *mentella* type is abundant in the North-west Atlantic where the water at the greater depths suited to adults of this form is generally moderately warm, and in the North-central and North-east Atlantic the *mentella* type is abundant, also, in areas where the warm North Atlantic water extends deeply into the *mentella* range.

7.

Redfish Distribution off Baffin Island, Northern Labrador, and in Ungava Bay in August—September 1959

By

WILFRED TEMPLEMAN

Fisheries Research Board of Canada Biological Station, St. John's, Nfld.

Introduction

During a cruise of the "A. T. Cameron", 18. August to 14. September 1959, a series of stations was worked, beginning with a line off Cape Dyer at the southern end of Baffin Bay and at the northern end of the Davis Strait Ridge in Lat. 66°42'–66°48'N and continuing southwards, usually on each degree of latitude line, as far as Lat. 58°N off Labrador, and also in Ungava Bay (Figure 1). At each station fishing by otter trawl was carried out in depths generally of 100 or 150 or both, 200, 250, 300, and 400 fathoms (180, 270, 370, 460, 500, and 730 m). The dragging period on bottom for each set was a half-hour. On the northern lines it was often impossible to take the 100 fathom (180 m) and sometimes the 150 fathom (270 m) drags because of ice. Dragging in all depths of 175 fathoms (320 m) and deeper was carried out in daylight, between sunrise and sunset. A commercial sized No. 41 otter trawl was used and the cod-end was lined with $1^1/8''$ mesh nylon netting. The towing speed was 3½ knots but 3 knots at 400 fathoms (730 m).

Redfish Catches

On Line I off Cape Dyer only two small redfish were found and on Line II, Lat. 66°N, only one. One hundred and fourteen redfish were obtained on Line III at Lat. 65°N, and thereafter on the more southern lines they were usually present in the sets in varying numbers. Only a few small redfish, however, were found in Ungava Bay. Details of the catches are shown in Table 1. No commercial catches of redfish were obtained over the whole area, the greatest quantities in a half-hour's dragging being about 500 lbs (230 kg) in 97 fathoms (543 m) at Lat. 64°N, and about 800 lbs 360 kg) in 305 fathoms (558 m) in Lat. 62°N. Especially in the northern part of the area the greatest redfish catches were taken at the 300 fathom (550 m) level.

Sizes, types, maturities, and larval drift

Table 2 shows the sizes of small redfish, 6–14 cm in length, and of females above these sizes, obtained in the different sets. Apart from a very small number of large *marinus*-type fish obtained at 300 fathoms (550 m) on all lines from 65°N to 62°N, all redfish definitely belonged to the *mentella* form typical of the Labrador/northern Grand Bank areas. That is, they were *mentella* with intermediate eye sizes, thick bodied and in good condition, with the usual long and thin dorsal spines, the most anterior pre-opercular spine usually projecting obliquely downward and forward, and the chin beak sharp angled, but short, having a base approximately as wide as the beak length.

Many *mentella*-type females up to 48 cm in length, a large size for this subspecies, were found from Lat. 64°N southwards, but although in the southern Canadian area *mentella*-type females become sexually mature at 30 cm or smaller, all females were immature as far south as Lat. 62°N. Surprisingly also, all 8 *marinus*-type females encountered between Lat. 65°N and 62°N, although they ranged in length from 54–65 cm, were immature. At Lat. 60°N off Cape Chidley, Labrador, only 3 % of 148 *mentella*-type females 30–48 cm in length were sexually mature, while further south at Lat. 58°N off Labrador, 40 % of 45 *mentella*-type females of 30–47 cm in length were sexually mature.

Small, 6–13 cm, *mentella*-type redfish were present in the catch from Line IV off Cumberland Sound (Lat. 64°N) to Ungava Bay, and were especially plentiful (173 individuals) at 155 fathoms (284 m) on Line V, north of Frobisher Bay (Lat. 63°N). There was a small number of these little redfish in Ungava Bay but none were found in the two lines at Lat. 60° and 58°N, off northern Labrador.

Since redfish larvae and fry live in the upper water layers for at least several months after extrusion and

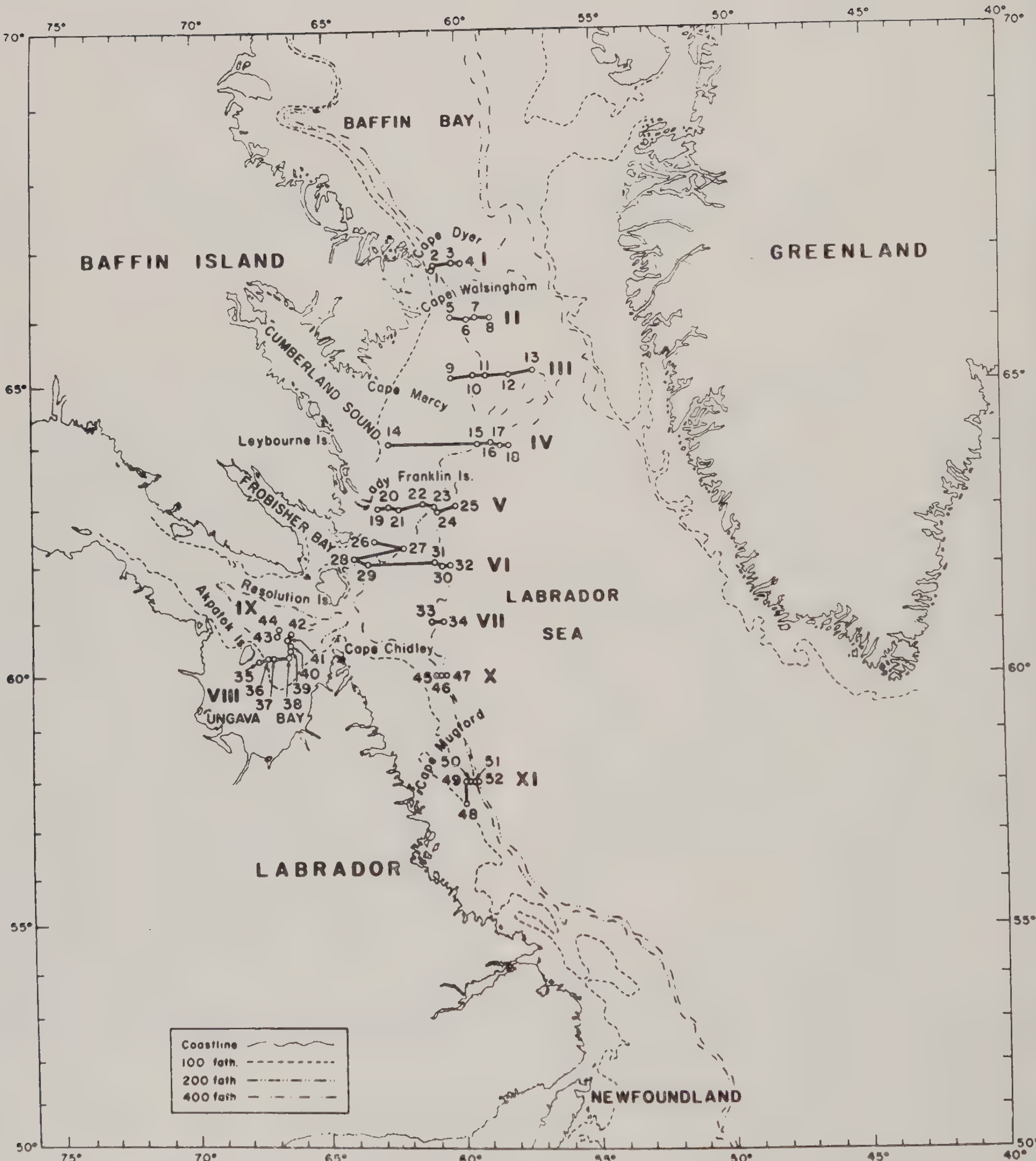
75°
70°
65°
60°
55°
50°
45°
40°
70°
65°
60°
55°
50°
BAFFIN BAY
BAFFIN ISLAND
GREENLAND
Cape Dyer
2 3 4 I
Cape Walsingham
5 7 6 8 II
9 11 13 10 12 III
CUMBERLAND SOUND
Cape Mercy
Leybourne Is.
14 15 17 16 18 IV
Lady Franklin Is.
20 22 23 19 21 24 25 V
FROBISHER BAY
26 27 31 28 29 32 30 VI
Resolution Is.
LABRADOR SEA
33 34 VII
IX
44 42 43
Akpatok Is.
41 40 39 35 36 37 38
VIII
UNGAVA BAY
Cape Chidley
45 47 46 X
Cape Mugford
50 51 49 52 48 XI
LABRADOR
NEWFOUNDLAND
Coastline
100 fath.
200 fath
400 fath

Figure 1. Location of otter-trawling sets by the "A. T. Cameron", 24. August to 10. September 1959.

Table 1. Catches of redfish in half-hour drags by the "A. T. Cameron", August—September, 1959

(1 pound = 0·45 kg.) (Time is the mid-time of the half-hour set in Atlantic standard time for the 60th meridian W. Four hours earlier than G.M.T.)

Set No.	Date	Time Atl. stand.	Position (mid-point of drag)		Depth range		Bottom temp. °C	Redfish captured	
			Lat. N	Long. W	Fathoms	Metres		*Mentella*-type Pounds	*Marinus*-type Pounds
Line I off Cape Dyer, Baffin Island									
1	Aug. 24	21·32	66°42′	60°55′	149–150	273–274	–1·05	0	0
2	„	18·10	66°47′	60°53′	200	366	–0·48	0·5	0
3	„	13·20	66°48′	60°10′	300	549	1·16	0	0
4	„	09·22	66°48′	59°49′	375–390	686–713	1·22	0	0
Line II off Cape Walsingham, Baffin Island									
5	Aug. 25	14·43	66°04′30″	60°27′	155–159	284–291	–0·39	0	0
6	„	10·33	66°02′	59°45′	200	366	0·31	0	0
7	„	06·38	66°04′	59°28′	287–300	525–549	–1·07	0	0
8	„	19·55	66°04′	59°00′	310	567	1·03	0·5	0
Line III off Cape Mercy, Baffin Island									
9	Aug. 27	20·40	65°05′	60°22′	150–155	274–284	0·25	0	0
10	„	17·00	65°07′	59°32′	200	366	1·05	0·3	0
11	„	12·44	65°07′	58°48′30″	248–250	454–457	1·28	11	0
12	Aug. 26	11·58	65°08′30″	58°10′	298–300	545–549	2·24	40	40
13	„	05·42	65°12′	58°13′	410–420	750–768	3·44	12	0
Line IV off Leybourne I., Cumberland Sound, Baffin Island									
14	Aug. 29	17·28	64°01′	62°54′	175	320	1·15	4	0
15	„	08·15	64°01′	59°28′	200–208	366–380	1·22	19	0
16	„	06·05	64°02′	58°43′	240–250	439–457	1·59	13	0
17	Aug. 28	07·47	64°00′	58°30′	294–300	538–549	2·29	499	16
18	„	16·10	64°00′	58°10′	400	732	3·52	0	0
Line V east of Lady Franklin I., Baffin Island									
19	Aug. 31	19·16	62°59′	63°00′	107–112	196–205	–1·36	0	0
20	„	13·15	63°00′	62°34′30″	125	229	–0·25	0·5	0
21	„	10·05	62°58′30″	62°13′30″	150–160	274–293	1·13	25	0
22	„	05·55	63°04′	61°20′	200	366	2·15	12	0
23	Aug. 30	17.49	63°00′	60°58′	250	457	1·84	25	0
24	„	05.57	62°55′	60°48′	288–300	527–549	2·07	211	7
25	„	10·45	63°01′	60°10′	395–398	722–728	3·57	3	5
Line VI off Frobisher Bay, Baffin Island									
26	Sept. 2	20·10	62°20′	63°13′	153–156	280–285	1·48	0·3	0
27	„	17·45	62°14′	62°55′	200	366	3·34	25	0
28*)	„	11·48	62°10′	64°02′30″	210	384	2·81	0	0
29	„	06·00	62°00′	63°08′	250–260	457–476	3·90	30	0
30	Sept. 1	15·55	62°00′	60°40′	300–310	549–567	3·78	767	18
31	„	07·20	62°02′	61°07′	300–310	549–567	4·10	45	0
32	„	13·10	62°00′	60°25′	390–410	713–750	4·07	57	0
Line VII off Hudson Strait									
33*)	Sept. 3	13·47	61°00′	61°05′	315–320	576–585	4·12	4	0
34*)	„	09·57	61°00′	60°53′30″	408–415	746–759	4·30	0	0
Line VIII Ungava Bay									
35	Sept. 6	06·35	60°16′	67°50′	27–28	49–51	1·98	0	0
36	Sept. 5	20·20	60°26′	67°00′	57–58	104–106	0·56	0	0
37	„	19·23	60°26′	66°59′	58–59	106–108	0·56	0	0
38	„	10·23	60°27′30″	66°20′	100–102	183–187	–0·60	0	0
39	„	07·13	60°33′	66°19′	148–155	271–284	0·19	0·2	0
40	Sept. 4	18·40	60°36′	66°19′	200	366	0·12	0·5	0
41	„	16·01	60°40′	66°21′	300	549	1·51	0·5	0
42	„	12·26	60°41′	66°20′	395–402	722–735	1·75	0	0
Line IX Ungava Bay									
43	Sept. 6	15·18	60°45′	67°02′	200	366	1·03	1	0
44	„	19·30	60°52′	67°00′	295–300	540–549	1·46	0	0

Unsuccessful sets; net torn badly; not on bottom etc.

Table 1 (continued)

Line X off Cape Chidley, Labrador									
45	Sept. 8	14·20	60°00′	60°57′30″	205	375	4·02	99	0
46	„	10·35	60°00′	60°53′	240–250	439–457	4·02	272	0
47	„	07.40	60°00′	60°50′	300–310	549–567	4·03	243	0
Line XI off Cape Mugford, Labrador									
48	Sept. 10	20·05	57°33′	59°52′	98–100	179–183	–0·39	0	0
49	„	14·31	58°00′	59°52′15″	150–160	274–293	3·25	10	0
50	„	11·48	58°00′	59°44′	200–210	366–384	3·88	118	0
51	„	09·10	58°00′	59°41′	300	549	4·07	123	0
52	„	06·22	58°00′	59°37′	410–420	750–768	4·03	32	0

since the course of the Labrador Current is rapidly southward, it is to be expected that larvae produced on the 58°N latitude line, where the most northerly significant numbers of sexually mature redfish occur, will generally settle a long distance southward. Also, from the lack of evidence of long migrations in redfish, it is to be expected that only very slow migrations of fish of gradually increasing size would occur from the settling area. The distribution of the small redfish found at the northern stations indicates recent settling and not northward migration.

The source of these young redfish, therefore, is evidently West Greenland. Although ages have not yet been estimated, the length of the more numerous group, with a peak length at 10–11 cm, indicates that they were possibly produced in 1957, a year when, as indicated by Hansen (1958), there was probably a greater than usual transfer of West Greenland water, with a resultant shift of cod larvae further west than usual. The same movement is indicated by the higher temperature conditions in 1957 in the deep water inhabited by redfish off Labrador and off the north-east Newfoundland Shelf (Templeman, 1958). From Table 2 it appears that there is also another age-group, one year younger, with a peak length of 8 cm. This group is dominant in Ungava Bay and is numerous also at the 155 fathom (284 m) level on Line V at about Lat. 63°N. If growth in this northern area is very slow it is possible that these smaller redfish, and not the 10–11 cm fish, were produced in 1957.

On the northern Lines III–V there were some 15–19 cm redfish and on Lines III–VI fair numbers of those between 20–24 cm. The 15–19 cm group was not represented, and the 20–24 cm group was extremely scarce, on Lines X and XI off northern Labrador. Similarly the 25–29 cm group was moderately numerous on Lines IV–VI off Baffin Island but scarcer off northern Labrador.

Thus, not only the distribution of the very young 6–14 cm redfish, but, also that of fish of 15–29 cm and even of 15–34 cm, indicates a settling of redfish fry in the northern area of Baffin Island, mainly between Lat. 64°—63°N, judging from Table 2, and also points to a spreading out, chiefly southward, from the settling area. These redfish also go into deeper water as they grow older. In some years there may be some settling southward to Lat. 62°N and some of the larvae or fry may be drawn into Ungava Bay. The scarcity of larger redfish in Ungava Bay (only one male of 20—24 cm and one female of 13 cm, in addition to the twelve females between 6–10 cm in length) indicates that the entrance of numerous redfish larvae into Ungava Bay, or at least their subsequent survival, is a rare occurrence.

Apart from 3 male and 8 female *marinus*-type redfish, all between 54 and 65 cm in length, the remaining approximately 2,800 fish captured were all *mentella* type. Since there were no small *marinus*-type redfish present on the Canadian side, the large *marinus*-type fish, 10 from 300 fathoms (550 m) and 1 from 400 fathoms (730 m), represent the downward extension of the occasional *marinus*-type fish from West Greenland on Line III, and either southward migration from the Davis Strait Ridge along the deeper parts of Lines IV–VI or recruitment from a pelagic population in the Labrador Sea.

Opposed to the latter idea and in favour of the former is the lack of captures of *marinus*-type redfish in Lines X and XI off northern Labrador.

On the other hand, the evidence available indicates that the *mentella*-type redfish of the area investigated come as larvae or larger fish from West Greenland. Although in the deep 300 fathom (550 m) water of Line IV, Lat. 64°N, there may be incursions of large *mentella*-type fish from along the southern edge of the Davis Strait Ridge, there is general evidence of settling of the *mentella*-type fry in the less deep, and rather cold water (a little over 1°C) off southern Baffin Island, especially at about 150–160 fathoms (270–290 m). There is also evidence of a growth to larger sizes as they pass deeper and spread out southward. Northward, the coldness of the water (–1°C at 150 fathoms (274 m), –0·5°C at 200 fathoms (366 m), and 1·2°C [illegible] and of female redfish from cruise of the "A. T. Cameron", August—September, 1959

(The frequencies, 15 cm and over, contain all female redfish both immature and mature, and the number of sexually mature females is shown in parentheses to the right of the total number of females at each size. All other females were immature. Lengths are chin to end of mid-fork of caudal fin, with mouth closed.)

Set No.	Position (mid-point of drag)		Depth		Bottom temp. °C	Length-frequencies (cm), *mentella*-type																Length-frequencies (cm), *marinus*-type females, immature				Total
						Unsexed									Females, immature and mature											
	Lat. N	Long. W	Fathoms	Metres		6	7	8	9	10	11	12	13	14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	54	55-59	60-64	65	
	Line I off Cape Dyer, Baffin Island																									
2	66°47′	60°53′	200	366	–0·48	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	1
	Line II off Cape Walsingham, Baffin Island																									
8	66°04′	59°00′	310	567	1·03	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	1
	Line III off Cape Mercy, Baffin Island																									
10	65°07′	59°32′	200	366	1·05	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	1
11	65°07′	58°48′30″	248–250	454–457	1·28	–	–	–	–	–	–	–	1	1	5	7	1	–	–	–	–	–	–	–	–	15
12	65°08′30″	58°10′	298–300	545–549	2·24	–	–	–	–	–	–	–	–	–	4	22	3	–	3	–	–	–	–	3	–	35
13	65°12′	58°13′	410–420	750–768	3·44	–	–	–	–	–	–	–	–	–	–	–	–	2	3	–	–	–	–	–	–	5
	Line IV off Leybourne I., Cumberland Sound, Baffin Island																									
14	64°01′	62°54′	175	320	1·15	–	–	2	1	11	7	1	–	–	–	1	–	–	–	–	–	–	–	–	–	23
15	64°01′	59°28′	200–208	366–380	1·22	–	1	–	–	–	–	–	1	–	13	24	2	–	–	–	–	–	–	–	–	41
16	64°02′	58°43′	240–250	439–457	1·59	–	–	–	–	–	–	–	–	–	5	7	2	1	–	–	–	–	–	–	–	15
17	64°00′	58°30′	294–300	538–549	2·29	–	–	–	–	–	–	–	–	–	2	62	61	61	43	22	4	1	–	1	–	257
	Line V east of Lady Franklin I., Baffin Island																									
20	63°00′	62°34′30″	125	229	–0·25	–	1	2	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4
21	62°58′30″	62°13′30″	150–160	274–293	1·13	–	10	19	4	56	65	16	3	–	1	2	–	–	–	–	–	–	–	–	–	176
22	63°04′	61°20′	200	366	2·15	–	–	–	–	–	–	1	–	1	5	21	3	–	–	–	–	–	–	–	–	31
23	63°00′	60°58′	250	457	1·84	–	–	–	–	–	–	–	–	–	–	29	10	2	–	–	–	–	–	–	–	41
24	62°55′	60°48′	288–300	527–549	0·07	–	–	–	–	–	–	1	–	–	2	75	41	20	12	5	–	–	–	1	–	157
	Line VI off Frobisher Bay, Baffin Island																									
26	62°20′	63°13′	153–156	280–285	1·48	–	–	1	–	–	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4
27	62°14′	62°55′	200	366	3·34	–	–	–	1	–	–	–	–	–	1	20	5	2	1	–	–	–	–	–	–	30
29	62°00′	63°08′	250–260	457–476	3·90	–	–	–	–	–	–	–	–	–	–	11	9	–	1	–	–	–	–	–	–	21
30	62°00′	60°40′	300–310	549–567	3·78	–	–	–	–	–	–	–	–	–	–	2	36	188	93	13	1	–	1	1	–	335
31	62°02′	61°07′	300–310	549–567	4·10	–	–	–	–	–	–	–	–	–	–	4	12	9	2	–	–	–	–	–	–	27
32	62°00′	60°25′	390–410	713–750	4·07	–	–	–	–	–	–	–	–	–	–	–	1	8	3	4	1	–	–	–	–	17
	Line VIII Ungava Bay																									
39	60°33′	66°19′	148–155	271–284	0·19	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
	Line IX Ungava Bay																									
43	60°45′	67°02′	200	366	1·03	1	3	6	1	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	12
	Line X off Cape Chidley, Labrador																									
45	60°00′	60°57′30″	205	375	4·02	–	–	–	–	–	–	–	–	–	–	–	1	7	21(2)	2	–	–	–	–	–	31
46	60°00′	60°53′	240–250	439–457	4·02	–	–	–	–	–	–	–	–	–	–	–	1	8	23	31	–	–	–	–	–	63
47	60°00′	60°50′	300–310	549–567	4·03	–	–	–	–	–	–	–	–	–	–	–	2	12	23(1)	17(1)	5(1)	–	–	–	–	59
	Line XI off Cape Mugford, Labrador																									
49	58°00′	59°52′15″	150–160	274–293	3·25	–	–	–	–	–	–	–	–	–	–	–	3	–	2(2)	–	–	–	–	–	–	5
50	58°00′	59°44′	200–210	366–384	3·88	–	–	–	–	–	–	–	–	–	–	1	2	4	14(11)	3(1)	–	–	–	–	–	24
51	58°00′	59°41′	300	549	4·07	–	–	–	–	–	–	–	–	–	–	–	2	4	8(2)	7(1)	1	–	–	–	–	22
52	58°00′	59°37′	410–420	750–768	4·03	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	2

at 300–390 fathoms (550–710 m) on Line I), prevents the northward extension of the redfish range and probably the success of survival of the floating larvae and fry, since rarely do they seem to be found deeper than 200 fathoms (370 m) (only 1 of a total of 224).

From West Greenland, Kotthaus and Krefft (1957; also see Templeman, 1959, Figs. 41 and 42) have found the *marinus*-type redfish to be the most common in their hauls, although some *mentella*-type redfish were caught. Only some of the hauls were taken, however, in typical *mentella* depths. Similarly Kotthaus (see Templeman, 1959) found 9 German landings of commercial redfish trawlers from West Greenland to be 100 % *marinus* type. Templeman (1959) found 61 redfish 7–33 cm in length from Tunugdliarfik Fjord in West Greenland to be all *mentella* type.

According to Dunbar (1951; after Kiilerich, 1939) most of the West Greenland Current, including the outer part of the current, leaves the Greenland slope between Godthaab (about Lat. 64°N) and Holsteinsborg (about Lat. 67°N). *Mentella*-type redfish are present in the deeper water of the West Greenland slope to seaward of the *marinus* type and thus may be more likely to be carried with the outer fringes of the West Greenland Current to the westward, in a latitude south of the Davis Strait Ridge. Most of the *marinus*-type larvae may pass northward as far as the Davis Strait Ridge on the West Greenland side, and may be lost by their penetration into the colder Baffin Bay area via the more easterly part of the West Greenland Current.

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APPENDIX TO SECTION II*)

Some Observations on Redfish in the Icelandic Area

By
ÁRNI FRIÐRIKSSON

1. Preamble

During the years 1935 to 1939 some of the cruises with the patrol vessel "Thor" in the waters round Iceland were devoted to preliminary redfish research. Even though the observations mentioned in this paper are 20–25 years old it is possible that they may be of ome use, since they relate to the first years of exploitation of redfish in the Icelandic area and they have never been published before.

In the summer of 1935 the herring fishery of the north coast of Iceland was poor and the processing plants lacked raw material for the production of oil and meal. It was known that very rich redfish grounds were situated off the north-west peninsula on the banks popularly called the "Halamið". Processing of redfish in herring oil and meal factories had never been tried before, but as the redfish liver, with its high content of itamins, would make a valuable by-product, the experiment to substitute the herring by redfish was arried out in August. The experiment was successful nd marked the start of the Icelandic redfish industry.

Early development of the fishery

In Table 1 a survey is given of the redfish landings n Europe in the thirties (1932–37) and the relative nportance of the Icelandic area with regard to edfish. During this period the total quantity landed ncreased about fourfold.

Table 1
European landings of redfish during 1932—37
(metric tons)

Year	(a) All European waters	(b) Icelandic waters	(b) as percentages of (a)
932	20,004	13,721	68·6
933	22,318	12,630	56·6
934	27,597	11,621	42·1
935	42,406	24,315	57·3
936	79,020	57,634	72·9
937	80,983	45,386	56·0
verages			
32–34...	23,306	12,057	51·7
35–37...	67,470	38,359	56·9

Table 2
German and Icelandic landings of redfish during 1932—37
(metric tons)

Year	German landings	Percentage of European landings	Icelandic landings	Percentage of European landings	German and Icelandic % of European landings
1932	16,162	80·8	357	1·8	82·6
1933	19,146	85·8	15	0·1	85·9
1934	23,401	84·8	607	2·2	87·0
1935	31,732	74·8	4,002	9·4	84·2
1936	49,554	62·7	23,053	29·2	91·9
1937	61,561	76·0	12,150	15·0	91·0
Average					
1932–34	19,517	84·0	326	1·4	85·4
1935–37	47,616	70·6	13,068	19·4	90·0

The rapid development which is revealed by the figures in Table 1 was mainly due to two causes – the German expansion of the high-sea fisheries and the Icelandic processing of redfish, both starting about the middle of the thirties. In Germany the redfish was mainly used for human consumption and on the markets was sold at similar prices as for instance, cod, which was higher than the average price for all other species landed. It is also seen that the major part of the catches came from the Icelandic grounds, which contributed about 42–73 % of the total European catch. The redfish from Iceland seemed to suit the German markets quite well, as only about 2 % of the landings (by number) were under the size-limit for marketable redfish (32·5 cm).

Table 2 shows the relative importance of the redfish for Germany and Iceland. In the case of Iceland the turning point was obviously in 1935, when processing was introduced. Before that time redfish was of practically no value to that country.

3. Abundance of redfish

The following section is mainly concerned with the first two cruises, which took place from 20. June to 12. August 1936, and from 23. May to 29. June 1937. Investigations were made all round the island, particularly far offshore. The fishing operations were carried

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*) This paper was submitted after the Symposium but it had been reed at the meeting that it should be included as an Appendix.

Table 3
Localities where the best redfish catches where made in June—August 1936

Station No.	Locality	Position N	Position W	Depth (m)	Date	Weight (kg) per one hour's trawling
8	off Reykjanes	63°58′8″	25°29′	241	21.VI	825
51	„ Kolbeinsey	67°06′9″	18°29′	160	2.VII	690
205	„ Hvalbak	64°16′2″	11°38′	374	27.VII	970
206	„ „	64°13′	11°36′	366	27.VII	3,000
209	„ „	64°10′	11°42′04″	366	28.VII	3,000
210	„ „	63°36′	11°15′	316	28.VII	840
247	„ Skagi	66°03′3″	20°53′	238	6.VIII	1,400

out by means of a V. D. trawl with a 75 feet headline and at a speed of about 3 knots when trawling in deep water. As the rather small grounds on the "Halamið" showed early signs of decreasing yields, the main task of the first cruise was to investigate the density of redfish at different places all round the coasts, in order to find new and profitable fishing grounds. Special efforts were made to find rich grounds off the east coast, to feed two new factories in Seydisfjörður and Nordfjörður.

In agreement with earlier experience the redfish was found to be very widely distributed, both horizontally and vertically as deep as the trawl could be used (about 500 m). On the other hand, there were relatively few localities where redfish was found in great quantities. The best localities, where the average catches per one hour's trawling ranged from about 700 to 3,000 kilos are shown in Table 3. A commercial trawler of that time with her larger gear (about 90 ft headline) and more powerful engine would have caught about 50 % more.

It is observed that the best grounds, the so-called "Thorsmið" (named after the vessel), yielded on an average 3 metric tons. Grounds which could not yield approximately that quantity would be of little use for commercial trawling, since the processing plants could pay no more than 3 aurar – approximately a farthing – per kilo. It should also be remembered that redfish fishing is relatively expensive owing to great depth, rough bottom, strong currents on the grounds, and an unusual amount of "wear and tear" on the net on account of the "spiny" nature of the fish.

Table 4
Water temperatures on the "Halamið" (1) and at a station 3 n. m. further NW (2) at the end of June, 1936

Depth	"Halamið" (1) 67°05′N–23°45′W °C	Cold water (2) 67°01·9′N–23°50′W °C
Surface	6·41	2·68
100 m	5·10	2·30
200 m	5·35	2·32
277 m	5·37	–
300 m	–	1·01
350 m	–	0·50

4. Occurrence in relation to water temperature

No trawling experiments were carried out on the well-known "Halamid" owing to shortage of time, but temperatures observed there revealed some extremely interesting features. It is sufficient to say that on the redfish grounds there was nearly pure Atlantic water from surface to bottom, whereas only 3 nautical miles further north-west, cold water masses predominated, as appears in Table 4.

At the first station (1) the depth was 280 m and 355 m at the other (2). It is evident that the dense occurrence of redfish was situated in the Atlantic water very near the boundary between the warm and cold water masses, this boundary being exactly vertical. Later there was an opportunity to ascertain that the boundary between the warm Irminger Current and the cold East Greenland Current in the Denmark Strait was like a vertical wall and just as sharply marked at the surface. Unfortunately no fishing experiments for redfish have been carried out in this area, but it is reasonable to believe that the greatest densities are found in the Atlantic water near the boundary of the Polar Current.

Bearing in mind the importance of the temperature gradients, new grounds were sought off the east coast where conditions similar to those off the north-west coast were supposed to prevail. Temperature measurements and trawling experiments gave a positive result. In 1936 the best catches were made on station 206, which was situated in the warm water area at 64°13′N –11°36′W (see Table 3), but at station 212 at 65°11′ 48″N–11°54′06″W, where the bottom temperature was only about 1°C, there were very few redfish.

In 1937 it was possible to compare the temperature conditions and to carry out experimental fishing on both sides of the temperature boundary, i.e. at stations 52 and 53. Both trawling and temperature observations occurred on the same day (16. June) and the positions of the stations were 64°14′12″N–11°47′W (Atlantic

Table 5
Temperature conditions at stations 52 and 53, 1937

Depth (m)	Station No. 52 °C	Station No. 53 °C
0	9·0	9·2
20	10·4	–
40	10·5	–
60	9·6	–
80	8·9	–
00	8·6	6·4
50	7·9	–
00	6·9	3·8
60	–	0·5
00	6·3	–

water) and 64°34′30″N–12°10′30″W (cold bottom water). The depth at station 52 was 348 m and at station 54 it was 263 m; the distance between them was about 20 n.m.

The main difference between the stations was obviously the bottom temperature. At station 52 the Atlantic water predominated from surface to bottom, whereas at 53 there was a layer of cold water near the bottom but the Atlantic water extended from the surface down to more than 100 m depth. The boundary between the warm and the cold water was therefore not vertical, as on the north-west coast, but was inclined, due to the fact that the cold water had penetrated under the warm water masses at the more northerly station.

Owing to the cold bottom layer there was a big difference between the fish fauna at these two stations, as is shown in Table 6, where the average number of fish of various species per hour's trawling is indicated. The main difference was in the density of redfish in the warm water and of cod in the cold water. It must be mentioned that nearly all the cod were immature, and it is interesting to recall that the nursery grounds for cod at Iceland are mostly in the cold water area, where the fish spends its life until the age of maturity approaches. It is not surprising that Atlantic species, such as *Argentina,* were limited to station 52, and Arctic species, such as *Reinhardtius,* to station 53. It is however, interesting to note that *Anarhichas minor,* which is a cold water species, was met with on the redfish grounds and, on the other hand, *Molva byrkelange* and *Gadus poutassou* (which are normally restricted to an Atlantic habitat) appeared in the catches from station 53. This indicates how close to the boundary, between warm and cold water, the great accumulations of redfish were situated.

Table 6
Number of fish per hour's trawling at stations 52 and 53

Species	Station 52	Station 53
ebastes marinus	948	93
rgentina silus	61	0
repanopsetta platessoides	7	27
olva byrkelange	6	5
adus poutassou	4	3
aja radiata	1	5
osmius brosme	1	9
narhichas minor	1	3
ippoglossus vulgaris	1	0
narhichas latifrons	0	3
upea harengus	0	4
adus callarias	0	377
einhardtius hippoglossoides	0	17

Table 7
Length distribution of redfish at stations 52 and 53 (⁰/₀)

Length group (cm)	Station 52	Station 53
10–14	–	1·6
15–19	–	3·2
20–24	–	8·1
25–29	–	1·6
30–34	0·5	21·0
35–39	3·3	19·4
40–44	43·0	6·5
45–49	48·1	6·5
50–54	2·5	8·1
55–59	1·4	11·2
60–64	0·2	11·2
65–69	0·2	1·6
70–74	0·6	–
75–79	0·2	–

Comparing the length distribution of the redfish from stations 52 and 53, as shown in Table 7, it may be noted that on the redfish grounds more than 91 % of the catch, by number, ranged between 40 and 50 cm in length, whereas these length groups were only slightly represented in the cold water catches, where relatively larger and smaller fish predominated. The total weight of redfish per one hour's fishing was 1,340 kg at station 52 but only 90 kg at station 53. It is most likely that the comparatively old and young redfish at station 53 "belong" to the cold water area, together with the other ichthyological elements which are found there, even though these fish were mixed with fish from the warm water. It is thought that the young redfish (30–39 cm and smaller) were mostly immature, and it is possible that some of the oldest fish (50 cm and upwards) do not migrate annually into the warm water for spawning. On the other hand, the medium-sized fish (40–50 cm) at station 52 certainly belonged to the active stock which is mainly carried by currents from the spawning area, and which accumulates at the boundary beween warm and cold water – exactly as in the Denmark Strait.

The theory of accumulation near temperature boundaries is supported by an important experience made by fishing vessels. In September 1935 a steam trawler, S/S "Brimir", went to the position where the largest density had been recorded earlier on the research cruise, but found practically no redfish. The skipper of "Thor" was sent to assist her and the following important facts were revealed:–

1. The boundary was situated somewhat further north.
2. There were great densities of redfish at the new boundary, yielding from 1 to 8·2 tons per hour or 4·6 tons on an average in an hour's haul.

Two areas have now been mentioned off Iceland, where warm and cold water masses border each other, viz., off the north-west peninsula and off the east coast. There is, however, a third region at the north-east corner, off Langanes. Temperature was measured in three localities in this area on 17. June 1937, at surface and bottom, the result being as shown in Table 8.

Table 8
Surface and bottom temperature at the north-east coast of Iceland

Station	Position	Depth (m)	Surface °C	Bottom °C
No. 54	67°09′N–14°43′W	308	6·25	2·68
No. 55	66°09′N–14°53′W	310	6·63	2·50
No. 57	67°15′N–15°11′W	338	6·62	0·04

It is obvious that at all three stations the Atlantic water was predominant at the surface and cold water at the bottom. As a consequence of this, the boundary between warm and cold water was quite different from that observed off the north-west and east coasts. The boundary was generally horizontal. In good agreement with this, only cold water species were caught by the trawl at the bottom, such as Greenland halibut, which was taken in large numbers, up to 1,200 fish or more in a single hour's haul. No redfish were found in this region. Redfish might perhaps, have been found in the warm water at some distance from the bottom, but with the primitive equipment of the vessel there was no opportunity to examine this possibility.

5. The problem of age and growth

In the hope that time could be found later to tackle this question, several thousand otoliths were collected. About 800 were cut, ground, and polished for easier age-reading. An attempt has been made, so far, to examine only some of the youngest specimens and the results are shown in Table 9.

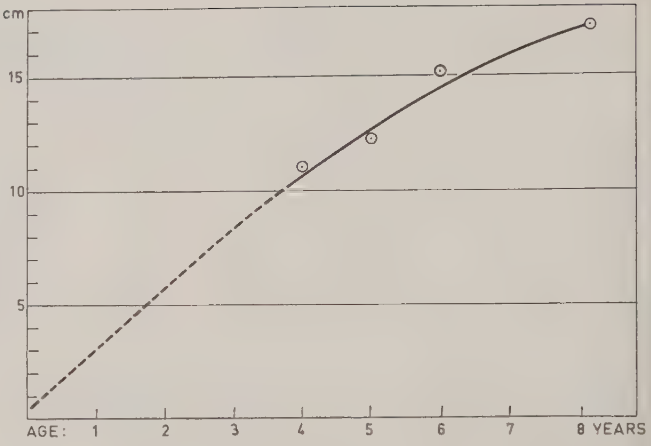

Figure 1.

Table 9
Age determinations of 85 young redfish

Length (cm)	4 years	5 years	6 years	8 years	Total
11	1	–	–	–	1
12	–	7	–	–	7
13	–	1	11	–	12
14	–	2	11	–	13
15	–	–	21	–	21
16	–	–	16	1	17
17	–	–	6	1	7
18	–	–	3	1	4
19	–	–	1	2	3
Total	1	10	69	5	85
Av. length	11·00	12·20	15·12	17·18	14·92

The otoliths examined were collected at deep-water stations off the west coast in April 1938. It has not yet been possible to establish how the "rings" in the redfish otoliths should be interpreted. If they are annual rings, the growth seems to be extremely slow. Starting with a larval length of 4–5 mm, the fish should have attained a total length of 17–18 cm only when 8 years old, corresponding to a growth-rate of a little more than 2 cm a year (see Figure 1). The age at first maturity should then be 15–20 years, and the largest individuals could be at least 50 years old or even much more.

6. Conclusion

It is indicated that the greatest accumulations of redfish, during summer, are found in Atlantic water near boundaries of cold water currents. It is reasonable to assume that instead of an active migration taking place after spawning, the fish are carried passively by the currents.

SECTION III

LARVAL STUDIES AND LARVAL DISTRIBUTION

Discussion Leader: Dr. H. EINARSSON

The following papers were presented and discussed:–

Ahlstrom, E. H. "Distribution and relative abundance of rockfish (*Sebastodes* spp.) larvae off California and Baja California."

Baranenkova, A. S., & Khokhlina, N. S. "The distribution and size composition of larvae and young redfish in the Norwegian and Barents Seas."

Corlett, J. "Distribution of redfish larvae in the western Barents Sea."

Corlett, J. "Redfish larvae from Ocean Weather Station 'A' in 62°N, 33°W."

Day, L. R. "Summer surface distribution of redfish larvae in ICNAF Subarea 4, 1954–55."

Einarsson, H. "Distribution, abundance, and size of young stages of *Sebastes* in Icelandic waters and adjacent seas."

Einarsson, H. "On the environment of the *Sebastes* larvae in the Irminger Sea."

Hansen, V. K., & Andersen, K. P. "Recent Danish investigations on the distribution of larvae of *Sebastes marinus* in the North Atlantic."

Henderson, G. T. "Continuous Plankton Records: The distribution of young stages of *Sebastes*."

Kelly, G. F., & Barker, A. M. "Vertical distribution of young redfish in the Gulf of Maine."

Tåning, Å. V. (Introduction by E. Bertelsen). "Larval and post-larval stages of *Sebastes* species and *Helicolenus dactylopterus*."

Templeman, W., & Sandeman, E. J. "Variations in caudal pigmentation in late-stage pre-extrusion larvae from *marinus*- and *mentella*-type female redfish from the Newfoundland area."

Wiborg, K. F. "The distribution of redfish larvae in Norwegian coastal and offshore waters during the years 1948–1958."

1. Identification of the larvae

Previously scientists in the European area have used Tåning's criteria to distinguish the larvae of the redfish, until recently believed to include only the species *Sebastes marinus* and *S. viviparus*. However, the general opinion of workers in this field in recent years is that "*mentella*"-type adults are also found and this introduces additional problems. We must ask where the larvae of the "*mentella*"-type adults are to be found, as no pigment spotted larvae similar to those distinguished by Templeman *et al.* as belonging with certainty to "*mentella*"-type parents have been reported in these oceanic waters.

The general opinion of the meeting appeared to be that the solution of this problem be furthered by the inclusion of pre-extrusion larval studies in the ICES area, and by an extension of the study of the planktonic larvae in the western Atlantic. There is some prospect that progress may shortly be made in this field, which might be assisted by an exchange of larval material between various workers.

It is felt most desirable that the drawings and notes prepared by the late Dr. Å. Vedel Tåning should be made available as widely as possible at the earliest possible date. (They are included, with Dr. Bertelsen's explanatory notes, at the end of this section.)

It might also be profitable to carry out some additional studies on the morphological and developmental characteristics of the larvae, with the purpose of determining some additional diagnostic features.

2. Horizontal distribution

A great deal of additional material relating to the distribution of *Sebastes* larvae was presented to the meeting, and the results from all workers supported a common distribution pattern in the North Atlantic. However, some deficiencies in sampling were noted. Among the suggestions made to overcome these deficiencies were an extension of plankton sampling from Weather Station 'ALFA' and the addition of a comparative section across the Irminger Sea to complement the results available from the 62°N section carried out by Danish workers.

3. Vertical distribution

It was thought that several aspects of the vertical distribution require further attention, in particular an assessment of the depth at which extrusion takes place. It was also felt that further effort was needed in the definition of the downward migration and the subsequent dispersal of the larval stock, so that this might be linked with the bottom or bathypelagic stages in the development. For this purpose it was thought that investigations both in the open sea and in the shelf region were needed, but that the sampling of the shelf waters might be more easily included in research programmes for next year.

4. Abundance

The results of all the surveys in the area show a generally similar pattern of annual fluctuations in abundance, and all agree in pointing to the year 1958 as an exceptionally poor year for *Sebastes* larvae in the North Atlantic. Danish investigations suggest that 1950 was an exceptionally prolific year. It is felt that a close study of associated data for 1958 might provide some evidence to explain the very low numbers of larvae found in this year compared with the larger numbers taken in previous years. Attention is drawn to the possibility of the evaluation of echo traces as an aid in observing changes in abundance.

5. Size composition of planktonic population of larvae

It is noted that the size composition of catches of larvae appears to indicate some degree of spread of modes, possibly as many as four minor ones, in the samples taken from the plankton. The general impression, however, is that they are *all* "the young of the year" and that the spread in sizes and the occurrence of several minor modes may be due to the fact that extrusion of young may last for a period of up to four months in some areas. The constant replenishment of the smallest sizes caught during a period when the larger sizes may be diminishing in particular sampling due to mortality, descent or dispersal, or even to avoidance, may well account for these peculiarities.

It is considered that some investigations are required in respect of the following matters:– (1) the size at which the larvae commence taking food, (2) the kind of food taken and a comparison with its availability, (3) and more difficult perhaps, some estimate of the duration of time between extrusion and the commencement of feeding.

6. Future work

It is considered that several of the contributions in this section point to the importance of relating the environment to the larval population, and that any further effort which can be made in this direction might well be of considerable value in any consideration of fluctuations in abundance from year to year as well as in assessing the variations in the onset of the first extrusion in any given year.

1.

Distribution and Relative Abundance of Rockfish (*Sebastodes* spp.) Larvae off California and Baja California

By

ELBERT H. AHLSTROM
Fishery Research Biologist, U. S. Bureau of Commercial Fisheries
Biological Laboratory, La Jolla

The information presented in this paper concerns the distribution and abundance of *Sebastodes* larvae in the area off California and Baja California that is surveyed by agencies participating in the California Cooperative Oceanic Fisheries Investigations. The pelagic distribution of rockfish larvae, especially their presence at considerable distances offshore, should be of interest, since it parallels, in part at least, the widespread oceanic distribution of *Sebastes* larvae in the North Atlantic.

The fishery for rockfish off the Pacific coast of North America is not as important as the Atlantic fishery for *Sebastes*. In the early years of the fishery, between 1916 and 1935, California landings averaged about 6 million pounds per year (range, 4·6–8·2 million pounds), and landings in the Pacific Northwest were less than 1 million pounds. There was nearly a twelvefold expansion in the Pacific catch of rockfish between 1940 and 1945, the landings increasing from 5·2 to 60·4 million pounds. Most of the increase occurred off Oregon and Washington. Since World War II, annual landings have fluctuated around 25 million pounds (Table 1). It is interesting to note that there has been a slow but steady rise in the California landings during the past 10 years: the 1958 catch of 17·6 million pounds was the largest on record.

The rockfish marketed off Oregon and Washington as the Pacific ocean perch is *Sebastodes alutus*; this species is not common off California. The bocaccio, *Sebastodes paucispinis*, is the dominant species in the California catch. Other important species are *S. serranoides, S. crameri, S. entomelas, S. diploproa* and *S. ruberrimus*. Most of the above information was obtained from Phillips (1958).

As background information, a brief account is given of the hydrographic-biological survey cruises being conducted under the California Cooperative Oceanic Fisheries Investigations (CCOFI). A basic purpose of the cruises is to supply observations for an understanding of oceanographic conditions off California and Baja California. An equally important purpose is the collection of data for the study of the distribution, abundance, and fluctuations in pelagic marine fish populations, particularly of the Pacific sardine (*Sardinops caerulea*). The distribution and amount of sardine spawning as well as the survival of sardine larvae are assessed annually. Information on the pelagic stages of other marine fishes is a by-product of this investigation.

Table 1
Total annual landings of rockfish along the Pacific coast of North America (in millions of pounds)

Year	California	Oregon and Washington	British Columbia and Alaska	Total
1936	4·6	0·6	0·4	5·6
1937	4·3	0·6	0·2	5·1
1938	3·6	0·7	0·7	5·0
1939	3·3	0·7	0·3	4·3
1940	3·6	1·3	0·3	5·2
1941	3·4	2·4	0·6	6·4
1942	1·4	3·6	0·7	5·7
1943	2·8	12·3	2·5	17·6
1944	6·4	20·8	3·9	31·1
1945	13·3	42·6	4·5	60·4
1946	11·2	23·3	3·5	38·0
1947	8·5	13·3	0·8	22·6
1948	6·5	15·4	1·2	23·1
1949	6·1	17·7	1·6	25·4
1950	8·1	18·3	0·7	27·1
1951	11·0	16·0	0·9	27·9
1952	10·7	20·2	0·9	31·8
1953	12·2	12·0	0·5	24·7
1954	12·6	19·5	0·5	32·6
1955	12·7	13·1	0·5	26·3
1956	14·9	*)	*)	*)
1957	15·9	*)	*)	*)
1958	17·6	*)	*)	*)

*) Not available.

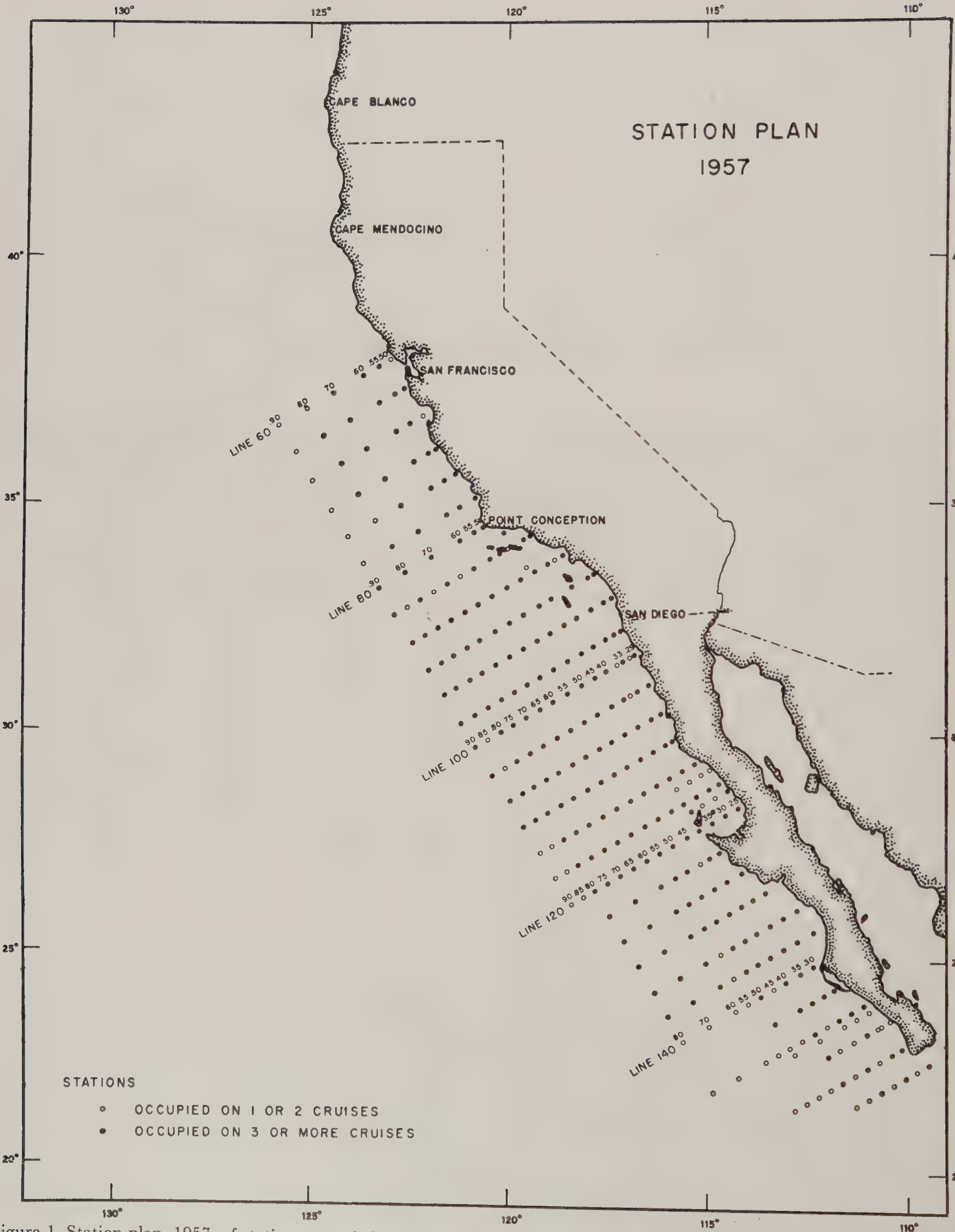
STATION PLAN
1957
CAPE BLANCO
CAPE MENDOCINO
SAN FRANCISCO
POINT CONCEPTION
SAN DIEGO
LINE 60
LINE 80
LINE 100
LINE 120
LINE 140
STATIONS
○ OCCUPIED ON 1 OR 2 CRUISES
● OCCUPIED ON 3 OR MORE CRUISES
130°
125°
120°
115°
110°
40°
35°
30°
25°
20°

Figure 1. Station plan, 1957, of stations occupied on cruises of the California Cooperative Oceanic Fisheries Investigations.

Cruises are usually made at monthly intervals, 2 to 4 research vessels participating. The U.S. Bureau of Commercial Fisheries operates a single research vessel, the "Black Douglas"; the remainder are operated by the Scripps Institution of Oceanography. The survey area is illustrated in the Station Plan, 1957 (Figure 1). Coverage is usually rather extensive during the first seven months of each year, partial during the last five months. Stations in the principal spawning areas of the sardine, i.e. between Point Conception, California, and Point San Juanico, Baja California, are usually occupied 9 or 10 times during the year; stations off central California and southern Baja California are seldom occupied more than 3 to 5 times per year.

Fish eggs and larvae are collected in plankton nets hauled obliquely from a depth of about 140 m to the surface. The nets are 1 m in diameter at the mouth by approximately 5 m in overall length. The main straining portion of the nets is constructed of No. 30 grit gauze, a heavy grade of Swiss bolting silk; the posterior portion, including the detachable cod-end, of No. 56 grit gauze. The openings between threads in No. 30 grit gauze are approximately 0·70 mm before use, but shrink to approximately 0·55 mm after use.

In taking a plankton haul, the research vessel moves ahead at a slow speed, usually between 1½ and 2 knots. The net is fastened by a bridle to the towing cable at a point which is approximately 10 m above a 100 lb weight. The net is lowered to its greatest depth (200 m of cable out) in approximately 4 minutes and retrieved at a rate of approximately 20 m of cable per minute. The total towing time is thus between 14 and 15 minutes per haul. During each haul, an inclinometer is suspended from the boom, riding freely on the towing wire. The angle-of-stray of the towing wire from the vertical is recorded at one-half minute intervals. Vessel speed is adjusted as necessary during the haul to keep the angle-of-stray of the towing wire as close to 45° as is possible. The depth of the net at any instant during a haul can be approximated by multiplying the amount of tow wire out by the cosine of the angle-of-stray of the towing wire from the vertical. The usual depth of hauls is between 130 and 145 metres.

The amount of water strained during each haul is determined from the revolutions registered by a current meter fastened in the mouth of the net. Hauls are put on a comparable basis by expressing all counts as numbers in a column of water under 10 m^3 of sea surface. Estimates expressed in this way are valid only if the vertical range of the organism has been encompassed. Studies on the vertical distribution of fish larvae have shown that rockfish larvae occur in the upper mixed layer and in the upper portion of the thermocline, but seldom deeper than this (Ahlstrom, 1959). Seventeen vertical distribution series containing *Sebastodes* larvae gave the following average depth distribution of the larvae:–

Depth of stratum (m)	Average weighted percentage in each stratum %
0–23	14·5
24–48	41·2
49–64	24·7
65–88	16·1
89–122	3·5
Below 122 m	0

Inasmuch as the standard plankton hauls sample a wider depth stratum than rockfish larvae are known to occupy, it is a safe assumption that their vertical range is routinely encompassed.

Sebastodes larvae

Scorpaenid fishes in the eastern North Pacific are given the common name of rockfish. The family Scorpaenidae is the largest family, in number of species, in the area that is being surveyed on cruises of the CCOFI. This region, which includes the waters off California and Baja California (and the Gulf of California), has approximately 61 species of scorpaenid fishes belonging to 5 genera: *Sebastodes, Sebastolobus, Scorpaena, Scorpaenodes,* and *Pontinus. Sebastodes,* by far the largest genus, has its centre of distribution off California. Forty-nine of the approximately 59 species of *Sebastodes* that are known to occur in the eastern North Pacific occur off California (Phillips, 1957). The southern limit of the distribution of the genus is in the vicinity of Magdalena Bay, Baja California. Two species apparently are endemic to the Gulf of California.

The genus *Sebastolobus,* with only two species in the eastern Pacific, interestingly enough, nearly encompasses the latitudinal distribution of the genus *Sebastodes*: Cape San Lucas, Baja California, to the Bering Sea. The other three genera are subtropical or tropical in distribution. There are about 10 species assigned to these genera in the eastern North Pacific. Eight occur off Baja California or in the Gulf of California, and only one, *Scorpaena guttata,* occurs as far north as southern California.

Scorpaenid larvae are readily distinguishable from those of other fish families. Their most characteristic feature is the paired parietal ridges on the back of the head, which terminate in spines. These first develop on larvae of 4 to 5 mm in length, and increase in prominence during the larval period. Each ridge ends in a single spine in *Sebastodes,* in a bifurcate spine in *Sebastolobus.*

Larger *Sebastodes* larvae can be distinguished from other scorpaenid larvae on the basis of meristics. Species of *Sebastodes* characteristically have 13 dorsal

Table 2

Relative abundance (standard haul totals) of the 12 most common kinds of fish larvae during 1957 in the area surveyed by CCOFI, compared with their contributions in 1955 and 1956

		1955			1956			1957	
	Number	%	Rank	Number	%	Rank	Number	%	Rank
Engraulis mordax	140,183	39·0	1	134,931	33·1	1	146,631	29·7	1
Merluccius productus	60,090	16·7	2	89,857	22·0	2	78,283	15·9	2
Vinciguerria lucetia	12,654	3·5	9	9,832	2·4	9	55,114	11·2	3
Sebastodes spp.	29,341	8·2	3	29,144	7·1	3	36,473	7·4	4
Leuroglossus stilbius	15,111	4·2	5	18,620	4·6	5	29,506	6·0	5
Trachurus symmetricus	13,246	3·7	7	8,027	2·0	10	20,006	4·0	6
Lampanyctus leucopsarus	7,454	2·1	10	15,125	3·7	7	16,808	3·4	7
Lampanyctus mexicanus	13,165	3·7	8	10,802	2·6	8	16,207	3·3	8
Citharichthys spp.	20,411	5·7	4	23,635	5·8	4	15,813	3·2	9
Diogenichthys laternatus	4,771	1·3	11	3,158	0·8	13	11,603	2·3	10
Sardinops caerulea	14,121	3·9	6	15,523	3·8	6	9,833	2·0	11
Bathylagus wesethi	3,245	0·9	12	2,146	0·5	17	6,347	1·3	12
All others	25,363	7·1		47,340	11·6		50,925	10·3	
Total	359,155	100·0		408,140	100·0		493,549	100·0	

spines. This character alone is sufficient to separate *Sebastodes* from other rockfishes in the eastern North Pacific, with the exception of *Scorpaenodes xyris.* There are but 12 dorsal spines in the species of *Scorpaena* and *Pontinus* that occur in the CCOFI area, 15 to 17 in *Sebastolobus.* The simplest character for separating *Scorpaenodes xyris* from *Sebastodes* is the number of dorsal rays: *S. xyris* almost always has 10, while species of *Sebastodes* have 12 or more.

All members of the genus *Sebastodes* give birth to young, i.e., are ovoviviparous. This mode of reproduction may be limited to this genus in the eastern Pacific, since both *Scorpaena* and *Sebastolobus* are known to lay their eggs in large masses. It is unlikely that any scorpaenid spawns free pelagic eggs – hence scorpaenid eggs are not a constituent of the plankton hauls.

The most recent three years for which data are complete have been chosen – 1955 through 1957 – to illustrate the distribution and abundance of *Sebastodes* larvae in the area being surveyed by the CCOFI. The basic data for these years are given in Ahlstrom and Kramer, 1957; Ahlstrom, 1958; and Ahlstrom, 1959. The abundance of larvae of *Sebastodes* are compared with those of other pelagic marine fishes in Table 2. In 1955, *Sebastodes* larvae constituted 8·2 % of the larvae obtained on the survey cruises; in 1956, 7·1 %; and in 1957, 7·4 %. In 1955 and 1956, *Sebastodes* larvae were exceeded in abundance by only two kinds of larvae: northern anchovy (*Engraulis mordax*) and Pacific hake (*Merluccius productus*). In 1957, *Sebastodes* larvae ranked 4th, behind northern anchovy, hake, and *Vinciguerria.*

Distributions of *Sebastodes* larvae during the three years, 1955–1957, are illustrated in Figures 2 to 4. The distributions are essentially similar in that the larvae are widespread throughout the survey area. The values shown on the charts are the average numbers of larvae obtained per haul at each station. This is a measure of relative abundance only.

The southern extent of the distribution of *Sebastodes* larvae has been delimited by these surveys, since this genus occurs only as far south as Magdalena Bay. The offshore distribution appears to be delimited off much of Baja California, but not off California, since *Sebastodes* larvae were obtained at some outer stations of the survey grid. Outer stations in the survey pattern off southern California are approximately 250 miles offshore.

The northern extent of the distribution is in no wise delimited by the CCOFI survey cruises. *Sebastodes* larvae are known to be common even in the Gulf of Alaska. There is evidence, however, that their centre of abundance is off southern California.

Ocurrences and abundance of rockfish larvae in different parts of the survey pattern are summarized in Table 3. The average number of larvae per haul for each area is given in the last column of the table. The largest value in all three years occurred in the area off southern California (station lines 80–93), although in one season, 1955, the average number per haul off central California (station lines 60–77) was nearly as large. Abundance off southern California was very similar in 1955 and 1956, but there was a marked increase in the average number of rockfish larvae obtained per haul in 1957. It is interesting to note that the frequency of their occurrences in this area has remained quite constant during these three years: between 62·7 % and 63·9 % of the collections made off southern California each year have contained *Sebastodes* larvae.

Seasonal distribution of *Sebastodes* larvae for the three years are summarized in Table 4. Because of the varying number of stations occupied per month, the values are given in terms of the average number of

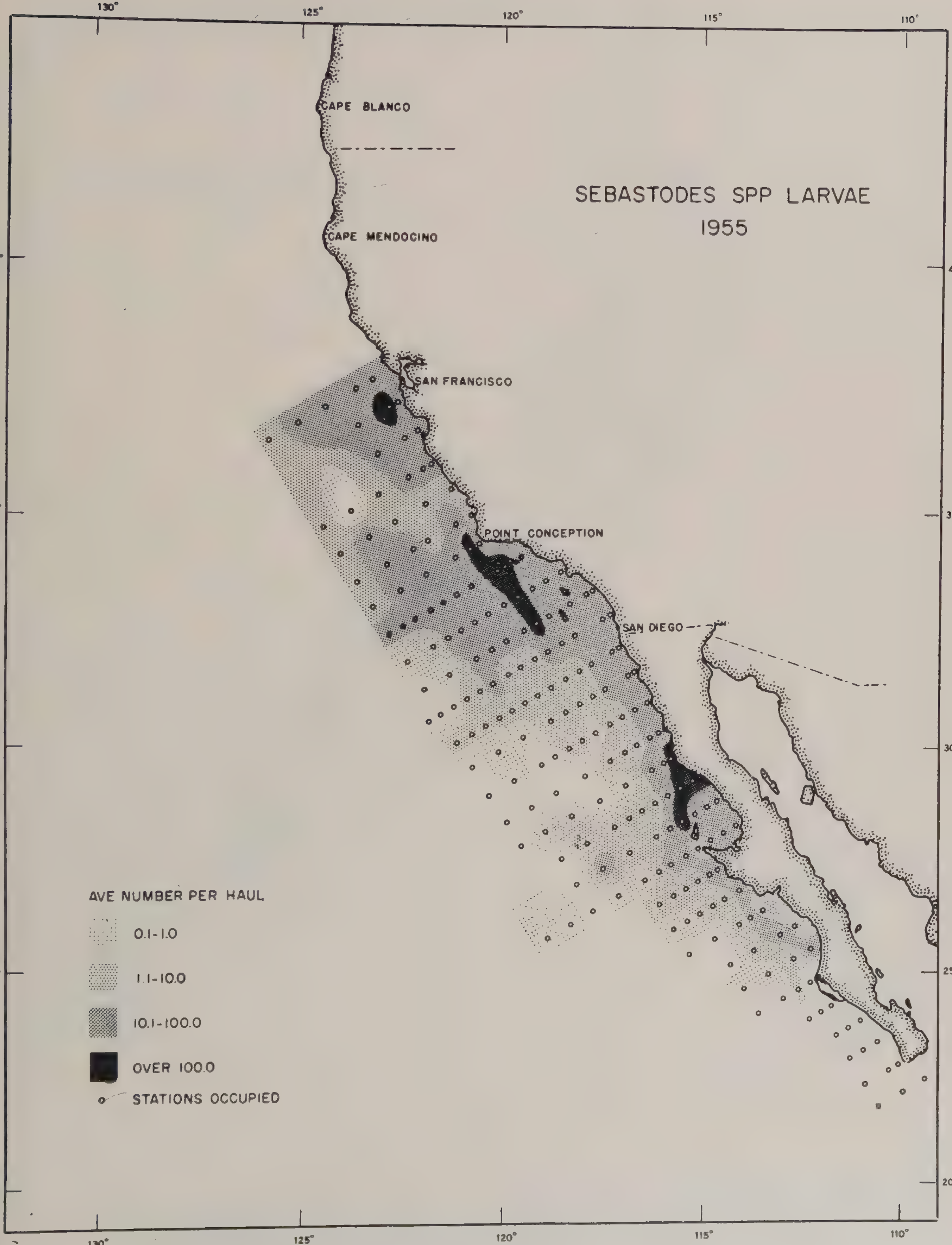
SEBASTODES SPP LARVAE
1955
CAPE BLANCO
CAPE MENDOCINO
SAN FRANCISCO
POINT CONCEPTION
SAN DIEGO
AVE NUMBER PER HAUL
0.1-1.0
1.1-10.0
10.1-100.0
OVER 100.0
STATIONS OCCUPIED
130°
125°
120°
115°
110°
40°
35°
30°
25°
20°

Figure 2. Distribution and relative abundance of rockfish (*Sebastodes* spp.) larvae in 1955.

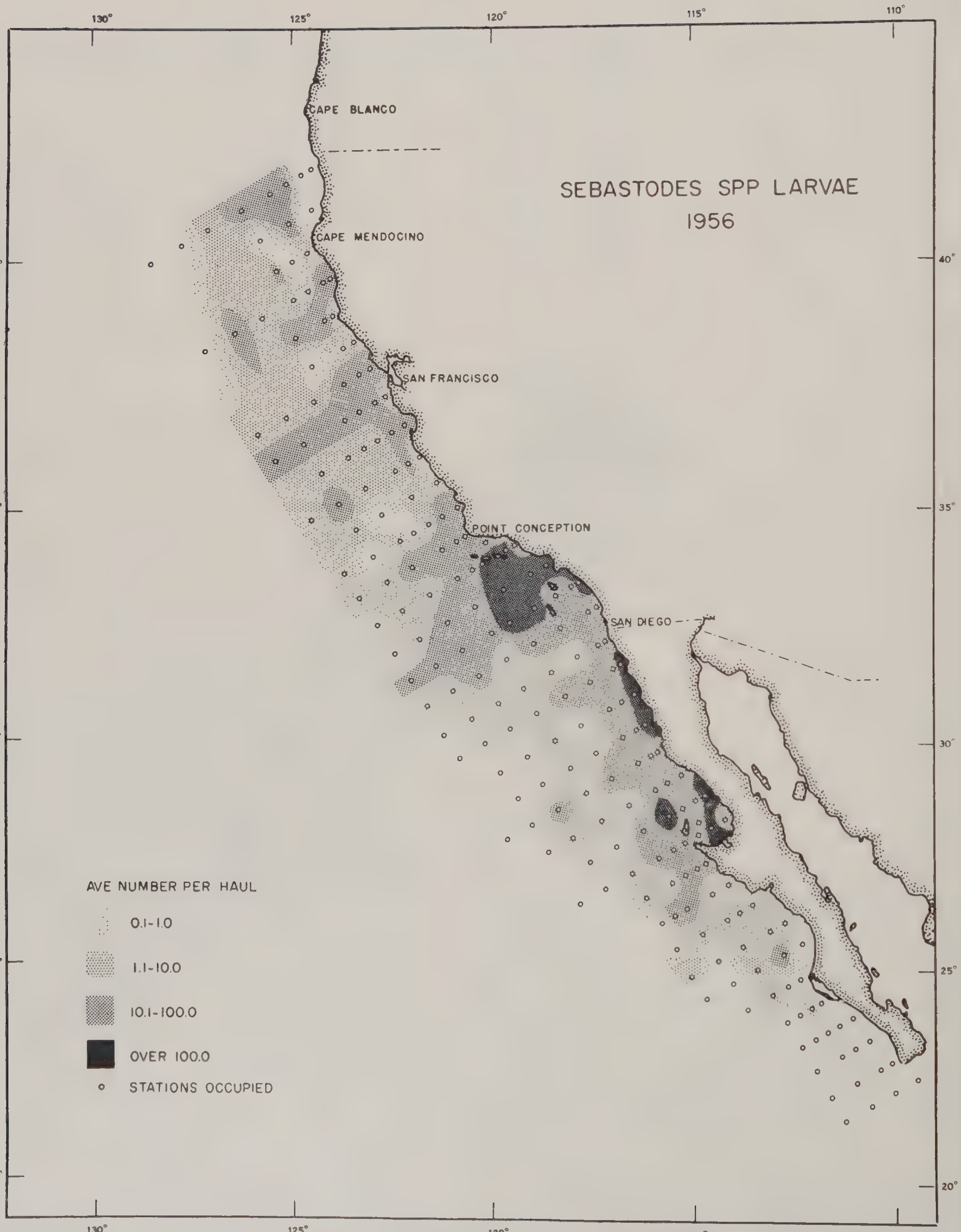
SEBASTODES SPP LARVAE
1956
CAPE BLANCO
CAPE MENDOCINO
SAN FRANCISCO
POINT CONCEPTION
SAN DIEGO
AVE NUMBER PER HAUL
0.1-1.0
1.1-10.0
10.1-100.0
OVER 100.0
STATIONS OCCUPIED
130°
125°
120°
115°
110°
40°
35°
30°
25°
20°

Figure 3. Distribution and relative abundance of rockfish (*Sebastodes* spp.) larvae in 1956.

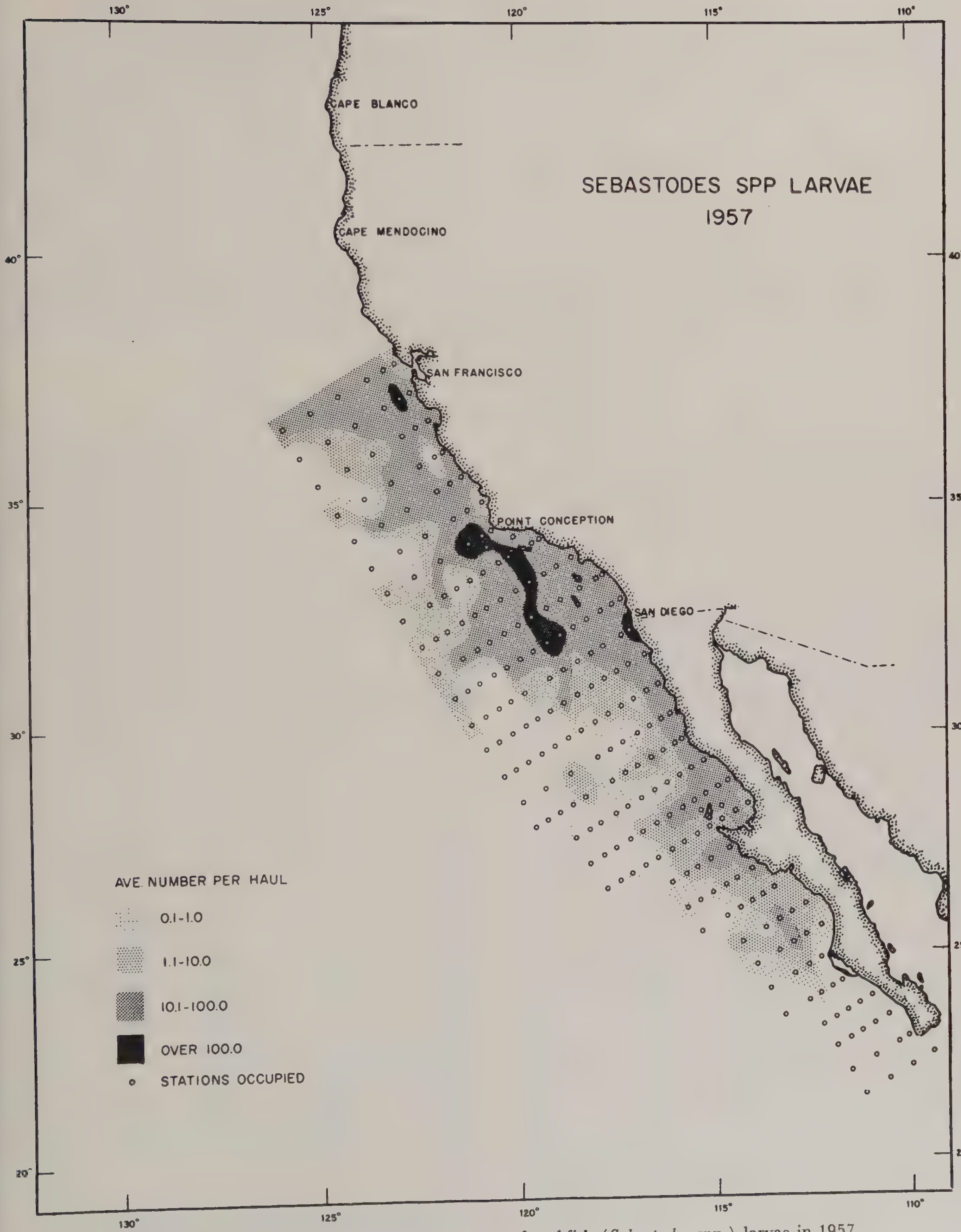
130°
125°
120°
115°
110°
CAPE BLANCO
SEBASTODES SPP LARVAE
1957
CAPE MENDOCINO
40°
SAN FRANCISCO
35°
POINT CONCEPTION
SAN DIEGO
30°
AVE. NUMBER PER HAUL
0.1-1.0
1.1-10.0
10.1-100.0
OVER 100.0
STATIONS OCCUPIED
25°
20°

Figure 4. Distribution and relative abundance of rockfish (*Sebastodes* spp.) larvae in 1957.

Table 3

Relative abundance of *Sebastodes* larvae in various parts of the area surveyed on cruises of the CCOFI, 1955—1957

Station lines	Number of samples	Occurrences of *Sebastodes* larvae	% occurrences	Total number of larvae	% taken in each area	Average number per haul
1955						
60–77	86	58	67·4	2,893	9·9	33·6
80–93	391	250	63·9	14,571	49·6	37·2
97–107	290	133	45·9	3,721	12·7	12·8
110–120	334	133	39·8	6,336	21·6	19·0
123–137	202	75	37·1	1,796	6·1	8·9
140–157	72	3	4·2	24	0·1	0·3
Total	1,375	652	47·4	29,341	100·0	20·6
1956						
40–57	54	24	44·4	411	1·4	7·6
60–77	112	59	52·6	1,570	5·4	14·0
80–93	393	247	62·9	14,674	50·4	37·3
97–107	274	97	35·4	4,703	16·1	17·2
110–120	308	112	36·4	6,306	21·6	20·5
123–137	180	65	36·1	1,424	4·9	7·9
140–157	76	10	13·2	56	0·2	0·7
Total	1,397	614	43·9	29,144	100·0	20·8
1957						
60–77	101	68	67·3	3,170	8·7	31·2
80–93	364	228	62·7	23,163	63·5	63·5
97–107	287	90	31·4	3,779	10·4	13·2
110–120	360	109	30·3	4,878	13·4	13·5
123–137	267	63	23·6	1,466	4·0	5·5
140–157	114	3	2·6	17	<0·1	0·1
Total	1,493	561	37·6	36,473	100·0	24·4

larvae per station (i.e., haul). The picture is a fairly consistent one. The largest number of *Sebastodes* larvae per haul usually is obtained in February, and higher than average numbers are taken from December through April. Low numbers per haul prevail during the months of June through October. Coverage of the survey area was restricted during most cruises made between August and December, hence values for this portion of the year are not as reliable as during January through July. Even allowing for this, it should not basically alter the seasonal pattern as outlined above. Most rockfish larvae are released during the winter and spring months. Inasmuch as a number of species of *Sebastodes* are included in the collections, most of them must have a similar seasonal pattern of reproductive activity.

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Table 4

Seasonal (monthly) abundance of *Sebastodes* larvae, 1955—1957

	1955			1956			1957		
	Number of stations occupied	Number of larvae	Average per station	Number of stations occupied	Number of larvae	Average per station	Number of stations occupied	Number of larvae	Average per station
January	112	6,281	56·1	110	4,293	39·0	57	1,010	17·1
February	117	6,206	53·0	130	7,717	59·4	142	11,001	77·5
March	142	3,653	25·7	134	6,404	47·8	124	6,585	53·1
April	134	3,533	26·3	178	2,887	16·2	207	7,225	34·9
May	184	1,895	10·3	239	2,286	9·5	205	4,819	23·5
June	189	1,732	9·2	209	1,584	7·6	253	2,742	10·8
July	196	2,676	13·7	201	1,489	7·4	217	1,383	6·4
August		Norpac		36	397	11·0	41	47	1·2
September	43	313	7·3	36	0	0	37	28	0·8
October	109	461	4·2	42	317	7·5	143	231	1·6
November	43	1,897	44·1	40	358	9·0	44	586	13·3
December	106	694	6·5	42	1,412	33·6	23	816	35·5
Total	1,375	29,341	21·3	1,397	29,144	20·9	1,493	36,473	24·4

2.

The Distribution and Size Composition of Larvae and Young Redfish in the Norwegian and Barents Seas

By
A. S. BARANENKOVA and N. S. KHOKHLINA
PINRO, Murmansk, U. S. S. R.

An examination of the summarized data on larvae, collected by the Polar Institute during 1934–1955, reveals that the redfish larvae first appear in the plankton off the north-western coasts of Norway, to the south-west of the Kopytov area, and in the eastern part of the central basin of the Norwegian Sea, in the latter half of April. The earliest date on which any redfish larva was observed was on 29. March 1951, on the Malangen Bank.

In May the number of larvae increases sharply in the catches taken off the north-western coast of Norway and on the continental slope over the deep water, northwards as far as 73°N. Newly liberated larvae and larvae of a greater size occur along the Norwegian coast as far east as 28°E and within the Spitsbergen Current up to 74°30′N (1946). They can also be found in the central part of the Norwegian Sea.

In June redfish larvae occur all over the Norwegian Sea except in the westernmost parts. Larvae are also found in the western Barents Sea as far north as 73°N, along the whole northern coast of Norway and the western Murman coast. Single specimens have been captured in the Motov Bay and in the Kolafjord. In the Spitsbergen Current larvae of redfish were found as far north as 74°32′N (1955).

In July the habitat of the larvae extends northwards and eastwards. In the Spitsbergen Current they have been found as far north as 76°44′N. In the Barents Sea larvae occurred up to the longitude of Teriberka, though they did not occur more easterly.

In August, small, recently liberated, 5–7 mm long larvae occur, together with larger ones of 10–16 mm in length.

It is most probable that the small redfish larvae found in July and August belong to the species *Sebastes viviparus.* Thus far there is no sufficiently clear method of identifying the specific composition of redfish at the larval stage. However, it has been observed that larvae in the coastal areas differ from those caught in the western part of the Kopytov area and to the south-west of it, i.e., in the area of great depths, in that their size is smaller and the body height relatively greater. The general picture of the distribution of redfish larvae in the Norwegian Sea is shown in Figures 1a and 1b (from Baranenkova *et al.,* 1956). The sizes of the larvae in different areas of the sea are shown in Tables 1 and 2 and Figures 2 and 3. (Places where larvae were found are shown by dots, and places where no larvae occurred by crosses.)

When a length of 15 mm is attained, the larvae transform into the young-fish stage (Schmitt, 1944). In this period they still live pelagically. Young redfish 17–30 mm in length were found in the stomachs of herring, caught on 11. August 1947 in the Spitsbergen Current. Single specimens of pelagic young fish still occur in later months.

The largest young redfish captured with pelagic gear had a length of 21 mm.

Young redfish were occasionally caught with bottom gear in the West Spitsbergen area and on the Central Plateau from October, and in the southern Barents Sea from November. In this period the young are 6–7 cm and longer, but settling begins when they are even smaller (4–5 cm).

The young redfish are widely distributed in the southern Barents Sea and in the Bear Island/Spitsbergen area; they do not occur in the shallow southeastern part of the sea. The presence of young fish one, two, or more years old in the bottom fishing gear (Sigsby trawl, otter trawl, beam trawl) in different

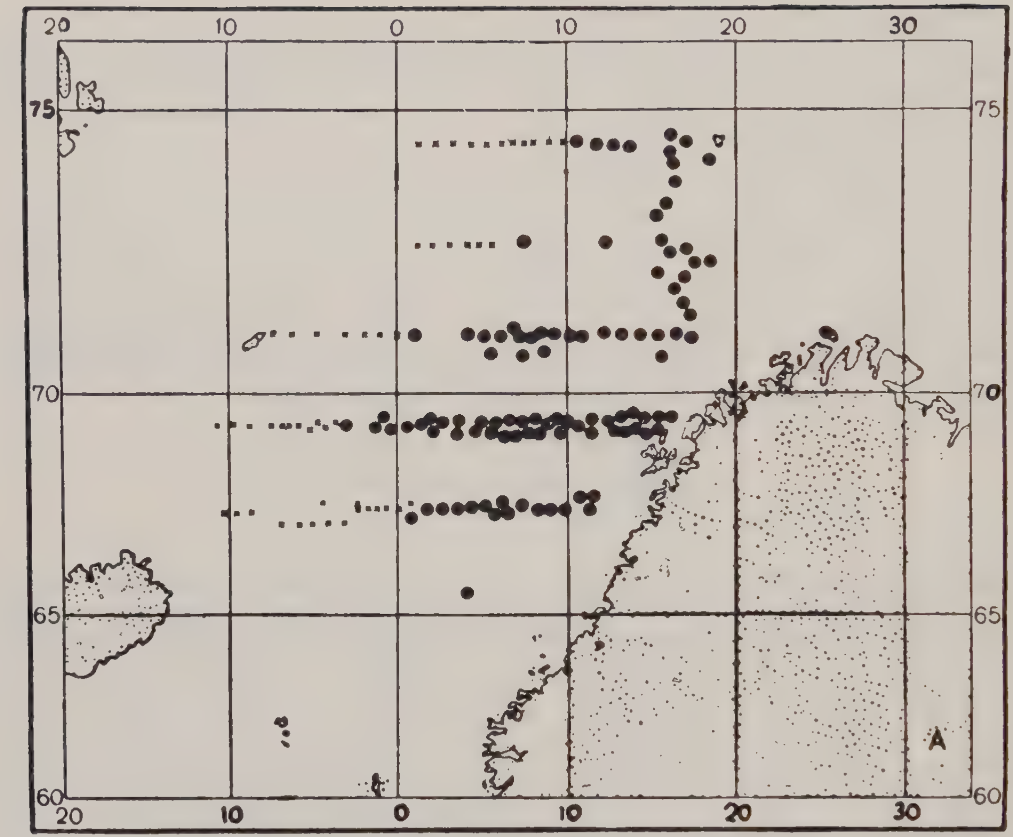

Figure 1a. Distribution of redfish larvae according to material sampled during 1951–1953. Small squares denote absence of larvae at the stations.

months of the year and in different Barents Sea areas has been noted by many investigators (Knipovich, 1904; Breitfuss, 1903, 1906, 1908; Rass, 1929; Veshchezerov, 1944). They encountered small specimens off the Murman coast, in the Motov Bay and the Kolafjord, on the Demidov Bank, and in the Bear Island area.

Figures 4a and 4b show the frequency of occurrence of young redfish measuring 5–10 cm and 11–15 cm, taken per hour by commercial trawl in the period 1946 to 1957. The majority of the hauls were mainly carried out in the autumn/winter season by means of a "cover" method, i.e., with a special net inside the cod-end with 10 mm mesh size between knots. It was not possible to determine to which species the young redfish belonged. It is not improbable that the *S. marinus* group incorporated other redfish forms. Only specimens with a clearly pronounced beak on the mandible were attributed to the *S. mentella* type. Some of the material is given without species definition.

Generally the young fish of the above size groups occurred in the same areas. The extreme eastern limits of young redfish were as far east as 52°E and as far north as 74°N. Their distribution was associated mainly with the principal flow of the warm current.

The presence of a considerable number of young *S. mentella* in one of the catches taken on the Rybachy Bank is worth mentioning (see Figure 4a). Most frequently the young *S. mentella* were found in the trawl catches on the Central Plateau. To the east of 35°E in the coastal regions and within the main flow of the current young *S. mentella* were not found, except once in the vicinity of the northern slope of the Goose Bank.

In the present material submitted only specimens having a length up to 16 cm have been considered. These sizes seem to embrace the young fish in the first three years of life.

Summarized calculation of the young redfish for a calendar year (Tables 3 and 4) clearly indicates a marked increase in number of specimens measuring 7, 10, and 15 cm in length. This is especially noticeable for *S. marinus* from the southern Barents Sea and the north-western regions (Table 4). It is thought prob-

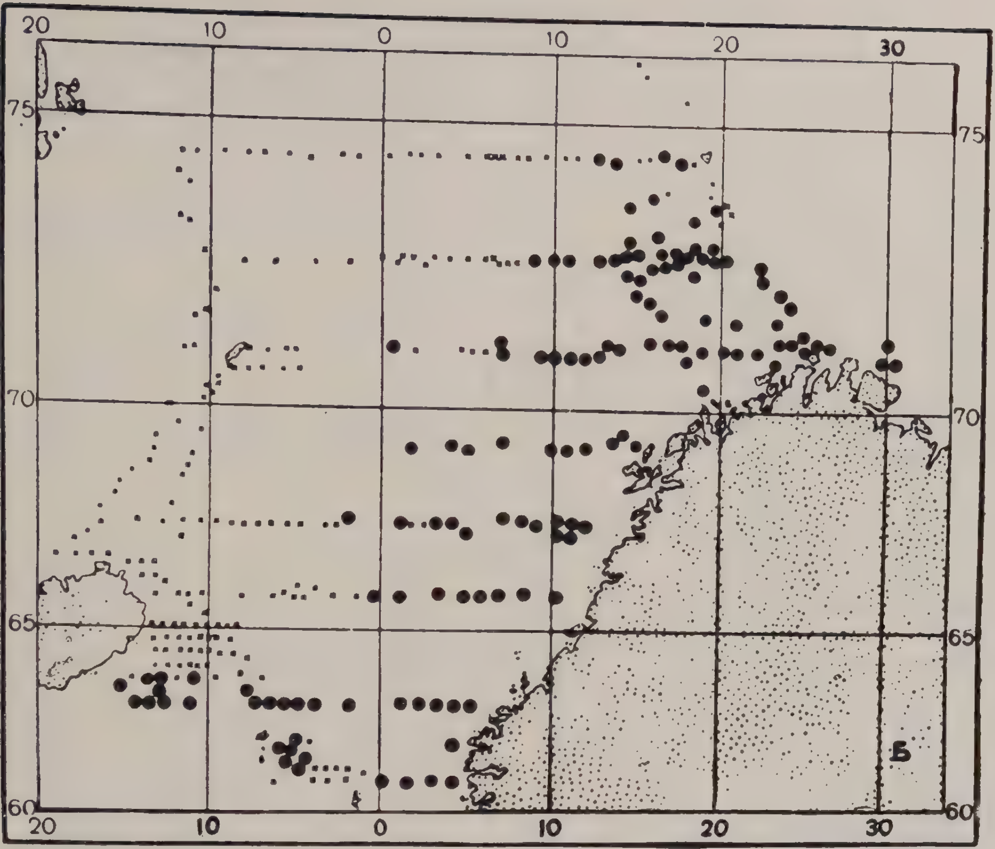

Figure 1b. Distribution of redfish larvae according to material sampled during 1954–1955. Small squares denote absence of larvae at the stations.

able that 7 and 10 cm long young redfish are specimens in their first and second year of life. These sizes correspond with the figures obtained by Travin (1951) for one and two year-old *S. mentella* by using the method of back calculation. Surkova, using this type of back calculation data, refers to the *S. mentella* specimens, measuring on average 12·2 cm, as three year-olds. Travin indicates a mean length for 3 year-old *S. mentella* of 13·09 cm, and for *S. marinus* of 12·87 cm. Veshchezerov (1944) calculated that *S. marinus* specimens with a mean length of 12·6 cm may be even four years old. He believed that one year-old *S. marinus* has an average length of 5·1 cm.

The analysis of the size composition of young redfish (Table 3) caught in May, (when the redfish is known to liberate larvae), i.e., at the time the fish accomplish their full first, second, or third year of life, has revealed an increase in abundance of young fish measuring 7–8, 12, and 15 cm. It is apparently those sizes that characterize the redfish specimens by the end of each of the first three years of life.

In 1959 two special cruises were organized by the Polar Institute. The pattern of liberation and the drift of eggs, larvae, and young commercial fish were studied aboard the R/V "Tunets" in the western Barents Sea and in the eastern Norwegian Sea, from the Lofoten Isles as far north as 75°N. In addition, studies were carried out simultaneously in March–May in the Kopytov area aboard the research trawler "Kharkov", one of whose tasks was to search for the places where *S. mentella* liberate their larvae.

Figures 5a and 5b show the distribution of redfish larvae in April/May 1959, according to the catches obtained by means of silk No. 140 egg-net of 80 cm diameter (5a, vertical haul; 5b, oblique haul). Figures 6a and 6b show the distribution in June/July of the same year (6a, by vertical haul with the egg-net; 6b, by oblique haul with the perlon ring trawl of 3 mm mesh and 160 cm diameter).

Figure 5 (a, b), showing the data of the two types of haul, presents a rather similar general picture of the redfish larvae distribution during late April/early May 1959. The larvae occur mainly in the zone between the 6° and the 7°C surface isotherms over depths

Table 1

Sizes of redfish larvae in the different areas of the Norwegian Sea

Month Year	Areas	Length (millimetres)												Number of specimens
		4	5	6	7	8	9	10	11	12	13	14	15	
May 1954	Central basin up to 69°18′N	–	5	56	186	154	25	3	–	–	–	–	–	429
June 1955	"Rosengarten" Bank	–	–	2	7	–	1	3	5	9	2	–	–	29
1954	Faroe area	–	1	3	5	2	2	3	2	5	3	6	1	33
1954	Viking Bank and southern Norwegian Gully as far as 60°57′ and 61°55′N	–	4	10	2	–	–	–	–	–	–	–	–	16
1954	Norwegian shallow and south-western area as far as 63°00′N	–	4	5	7	2	–	–	–	–	1	–	–	19
1954	Norwegian shallow up to 65°45′N	1	8	9	7	–	5	1	3	2	2	2	1	41
1955	Norwegian shallow up to 65°45′N	–	4	15	8	4	–	–	–	–	–	–	–	31
1951	Norwegian Plateau up to 65°24′N	–	1	23	51	12	–	–	–	–	–	–	–	87
1954	Norwegian Plateau up to 65°45′N	–	–	2	17	4	1	–	–	–	–	–	–	24
1955	Norwegian Plateau up to 65°45′N	–	–	27	42	17	1	–	1	–	–	–	–	88
1954	Central basin up to 65°45′N	–	–	1	3	6	2	–	–	–	–	–	–	12
1951	Lofoten shallow up to 67°30′N	–	3	13	17	15	2	1	–	–	–	–	–	51
1954	Lofoten shallow up to 67°30′N	–	–	2	15	9	5	4	–	–	–	–	–	35
1955	Lofoten shallow up to 67°30′N	3	42	54	10	2	–	–	–	–	–	–	–	111
1951	Norwegian Plateau up to 67°30′N	–	2	10	27	12	–	–	–	–	–	–	–	51
1954	Norwegian Plateau up to 67°30′N	–	–	5	23	20	13	4	1	–	–	–	–	66
1955	Norwegian Plateau up to 67°30′N	–	–	6	17	1	2	–	–	–	–	–	–	26
1954	Central basin as far as 67°30′N	–	–	–	–	–	2	1	1	1	–	–	–	5
1951	Central basin as far as 70°50′N	–	–	2	15	44	64	21	3	–	–	–	–	149
1952	Central Plateau up to 71°10′N	–	–	62	225	132	53	14	9	–	–	–	–	495
1953	Central Plateau up to 71°10′N	–	–	1	16	30	11	6	–	1	–	–	–	65
1954	Central Plateau up to 71°10′N	–	–	6	17	19	9	4	–	–	–	–	–	55
1955	Central Plateau up to 72°50′N	–	1	97	137	72	38	14	1	–	–	–	–	360
1948	Westwards of Bear Island up to 74°20′N	–	–	2	40	87	81	37	7	3	1	–	–	258
1952	Westwards of Bear Island up to 74°20′N	–	–	–	1	1	1	15	19	3	3	3	–	46
1954	Westwards of Bear Island up to 74°30′N	–	–	–	1	1	–	–	–	–	–	–	–	2
1955	Westwards of Bear Island up to 74°30′N	–	–	7	30	73	147	167	53	19	–	1	–	497

Table 2

Sizes of redfish larvae in the Norwegian Sea during 1934—1955, by months (%)

Length (mm)	Months					Number of specimens
	April	May	June	July	August	
3	–	0·3	–	–	–	26
4	4·5	1·4	0·2	0·8	–	148
5	12·9	10·5	2·6	0·7	9·8	1,158
6	35·6	36·0	13·3	0·5	9·8	4,312
7	28·0	37·2	23·2	2·0	9·8	5,303
8	12·9	11·9	19·6	4·7	11·8	2,813
9	5·3	1·7	15·8	12·7	25·5	1,649
10	–	0·6	11·1	28·0	5·9	1,212
11	0·8	0·3	7·0	18·5	3·9	764
12	–	0·08	4·1	14·2	3·9	462
13	–	0·05	2·0	7·5	9·8	229
14	–	0·001	0·8	4·0	3·9	95
15	–	–	0·2	2·5	3·9	31
16	–	–	0·07	1·8	2·0	18
17	–	–	0·01	1·1	–	8
18	–	–	–	0·2	–	1
19	–	–	0·01	–	–	1
20	–	–	–	–	–	–
21	–	–	–	0·8	–	5
Number of specimens	132	8,566	8,886	600	51	18,235

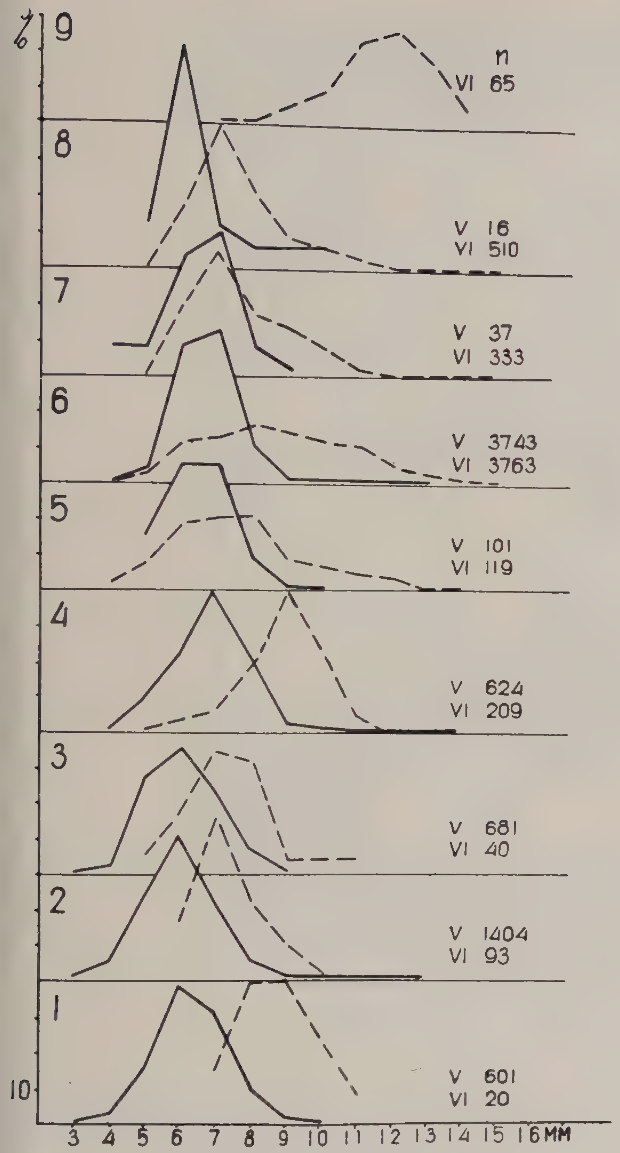

Figure 2. The sizes of redfish larvae by areas, in total, during 1934–1955.
(Whole line = May; dashed line = June)

1. Vesterålen Bank
2. Andenes Bank
3. Malangen Bank
4. Fugløy Bank
5. Sørøya Bank
6. Kopytov area
7. Westwards of Kopytov area
8. Western slope of the Bear Island Bank
9. Southern slope of the Bear Island Bank

greater than 1000 m. It is characteristic that in the catches taken from the coastal areas in late April, no redfish larvae were found. The length of the larvae, 6–8 mm, suggests that they had been recently released. Most of them had a length of 7 mm, and some possessed a small oil globule. It may be noticed that larvae taken in the Kopytov area from a *S. mentella* female ready to liberate larvae had a length of 7 mm.

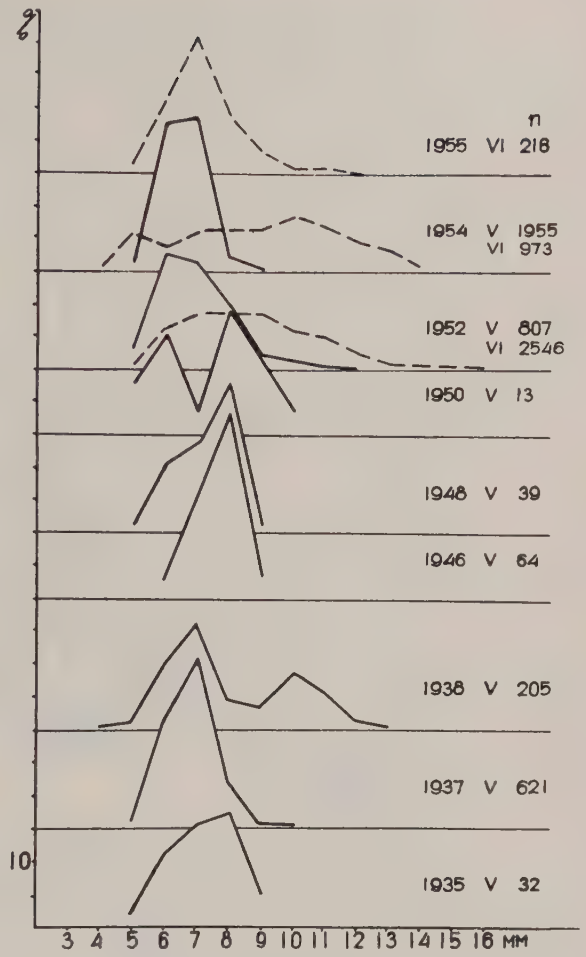

Figure 3. The sizes of redfish larvae in the Kopytov area and westwards in different years.
(Whole line = May; dashed line = June).

On the basis of observations of the maturity of *S. mentella* females, the occurrence of spent individuals, and the appearance of larvae in plankton hauls, Sorokin has come to the conclusion, that in 1959 mass liberation of *S. mentella* larvae commenced in the period between 25. April and 2–3. May. Most of the larvae were 7–8 mm long. Single specimens showed a length of 6·5 mm.

In May the larvae occurred in the catches in increasing numbers.

As yet it cannot be said definitely to what species of redfish the larvae belonged. It may, however, be supposed that most of them belonged to *S. mentella,* as great quantities of *S. mentella* females, ready for the liberation of larvae, were found in that period in the Kopytov area, near the slope.

Catches of larvae were made from 4. June to 16. July (see Figure 6, a and b). To the west of the section North Cape/Bear Island, larvae were collected in June,

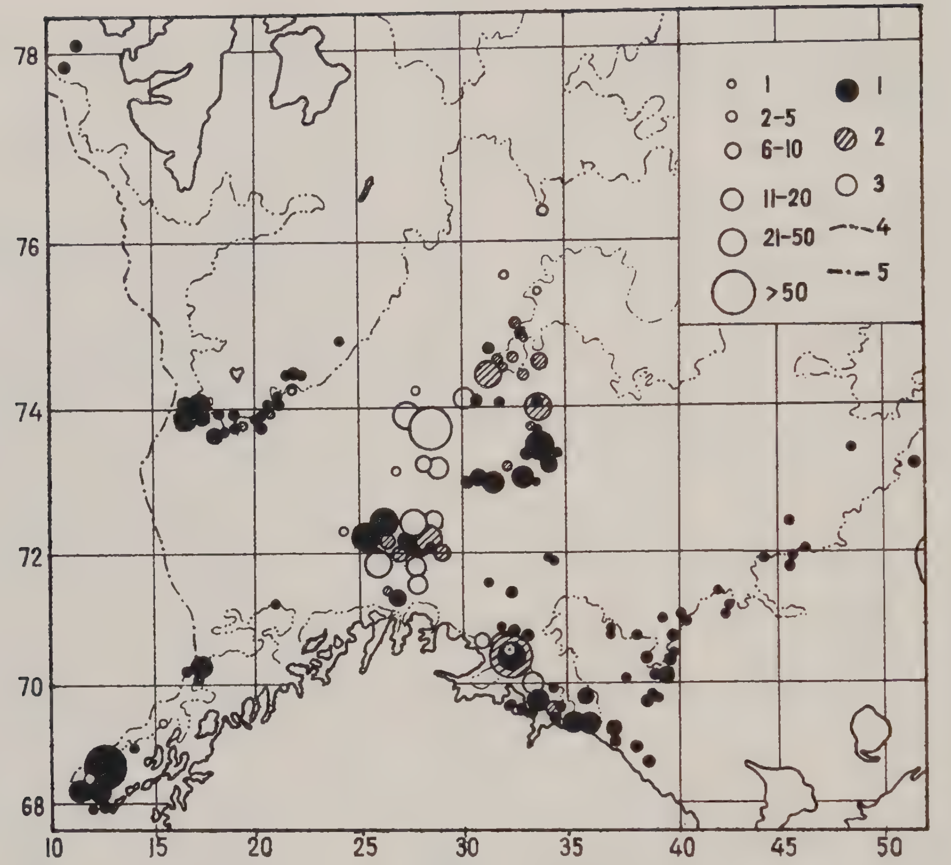

Figure 4a. Distribution of the trawl catches in which young redfish of 5–10 cm length were present in 1946–1957. The number of young caught during one hour of trawling is indicated by circles of different sizes.

1 = *S. marinus*
2 = *S. mentella*
3 = Species of young not identified
4 = 200 m isobath
5 = 1000 m isobath

Table 3

Sizes of young redfish by months, in all areas of the Barents Sea during 1946—1957

Length (cm)	Months												
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Total
5	–	6	2	1	1	–	–	–	–	–	–	–	10
6	20	86	40	27	11	–	–	–	–	2	1	6	193
7	26	225	108	48	81	3	–	–	–	2	5	5	503
8	23	47	31	6	121	1	–	–	–	2	–	5	236
9	37	67	27	8	31	1	–	–	–	–	7	13	191
10	65	51	43	10	10	3	–	–	–	8	5	17	212
11	55	44	29	5	11	7	1	–	1	2	10	19	184
12	40	92	64	14	14	9	–	2	1	6	13	45	300
13	45	127	72	13	6	7	–	1	7	4	14	46	342
14	39	166	106	22	12	18	5	1	5	6	14	71	465
15	65	184	173	44	18	15	7	2	19	16	35	68	646
Number of specimens	415	1095	695	198	316	64	13	6	33	48	104	295	3,282

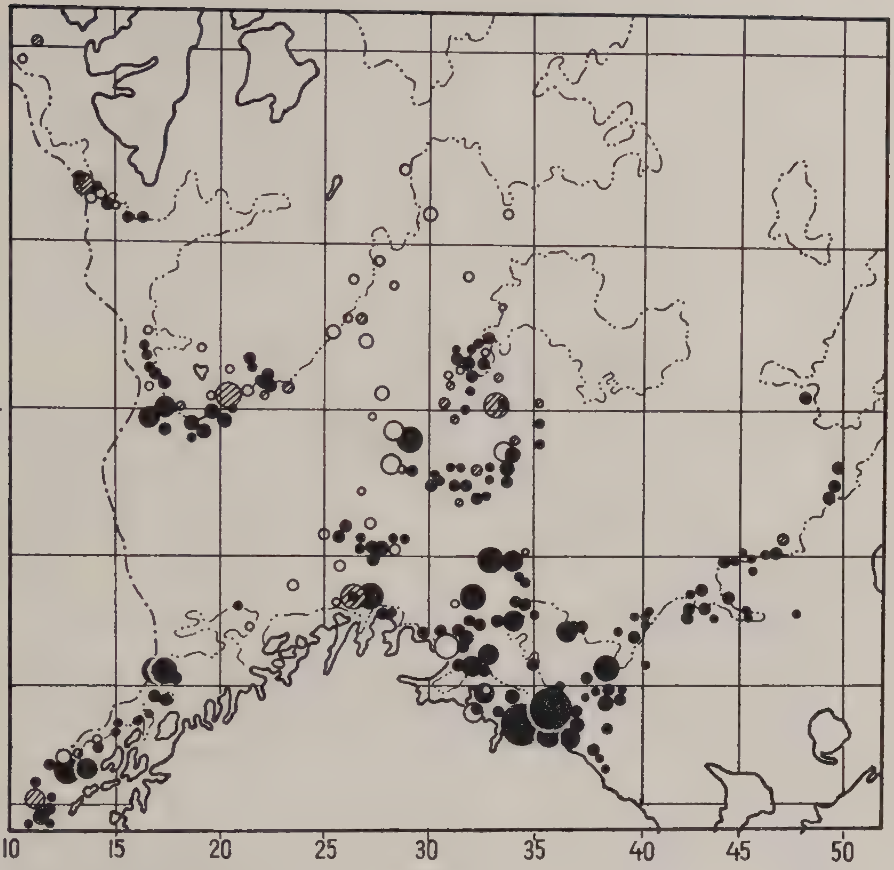

Figure 4b. Distribution of trawl catches containing young redfish of 11–15 cm length in 1946–1957. The number of young caught during one hour of trawling is indicated by circles of different sizes. (For key, see Fig. 4a.)

Table 4

Sizes of the young redfish from trawl catches, by areas, in total, during 1946—1957

	Sebastes marinus				*Sebastes mentella*				Total		
Length (cm)	Southern part of Barents Sea	Central Plateau	NW areas of Barents Sea	NW coast of Norway	Southern part of Barents Sea	Central Plateau	NW areas of Barents Sea	NW coast of Norway	*S. marinus*	*S. mentella*	Grand Total
5	6	1	1	–	–	2	–	–	8	2	10
6	118	14	8	1	34	15	3	–	141	52	193
7	235	24	39	1	163	36	2	3	299	204	503
8	124	2	25	16	56	5	1	7	167	69	236
9	92	2	31	46	10	1	–	9	171	20	191
10	118	8	41	34	3	1	2	5	201	11	212
11	111	8	35	20	3	1	3	3	174	10	184
12	212	8	36	24	3	3	3	11	280	20	300
13	227	8	37	46	4	5	8	7	318	24	342
14	290	4	42	80	4	17	16	12	416	49	465
15	316	5	66	146	26	19	41	27	533	113	646
Number of Specimens ..	1,849	84	361	414	306	105	79	84	2,708	574	3,282

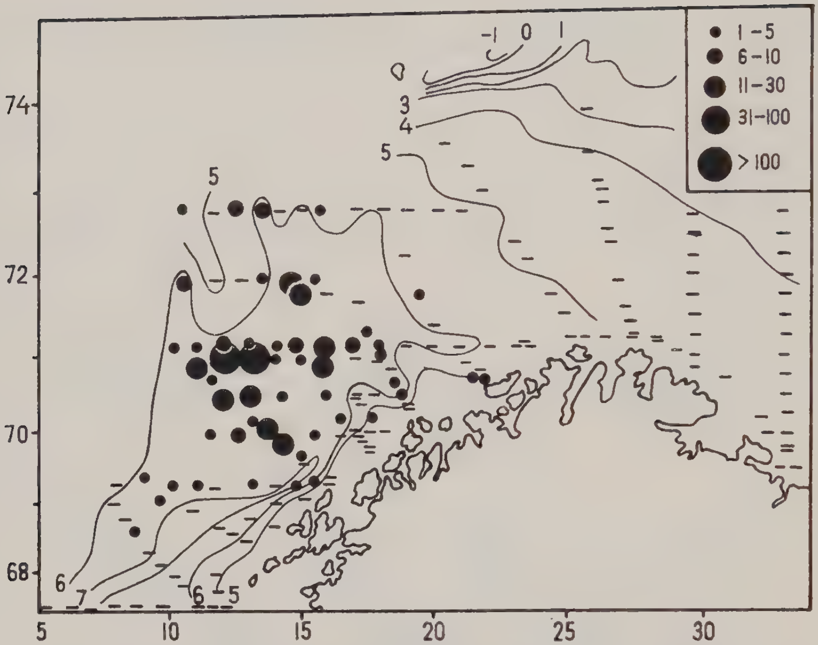
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Figure 5a. Distribution of redfish larvae according to the data of vertical catch (bottom to surface) taken with the egg-net, and the surface isotherms in April/May 1959. The dashes indicate absence of larvae in the catch. Circles of different sizes indicate the number of larvae caught per haul.

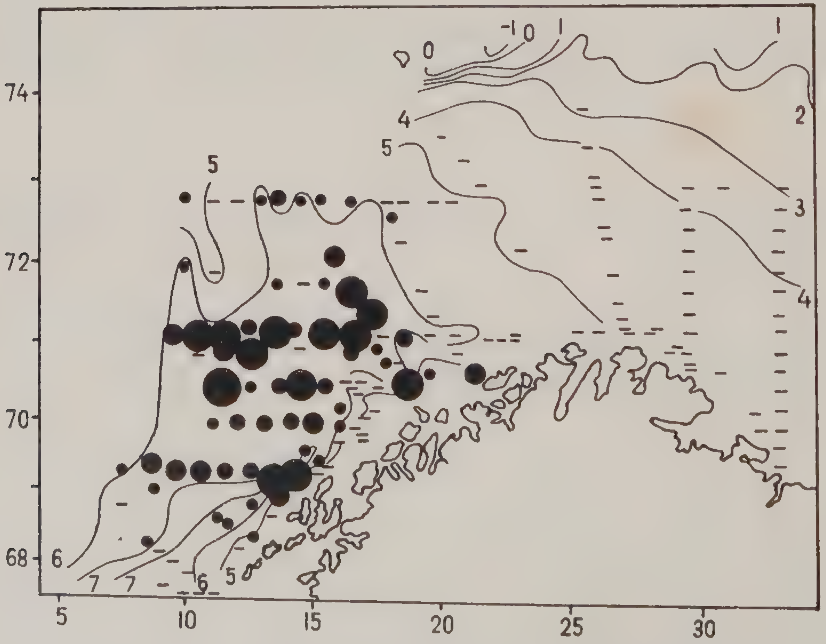
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Figure 5b. Distribution of redfish larvae according to the data of oblique haul (25 m to surface) made with the egg-net from a boat circling for 10 minutes. April-May 1959. Key as for Figure 5a.

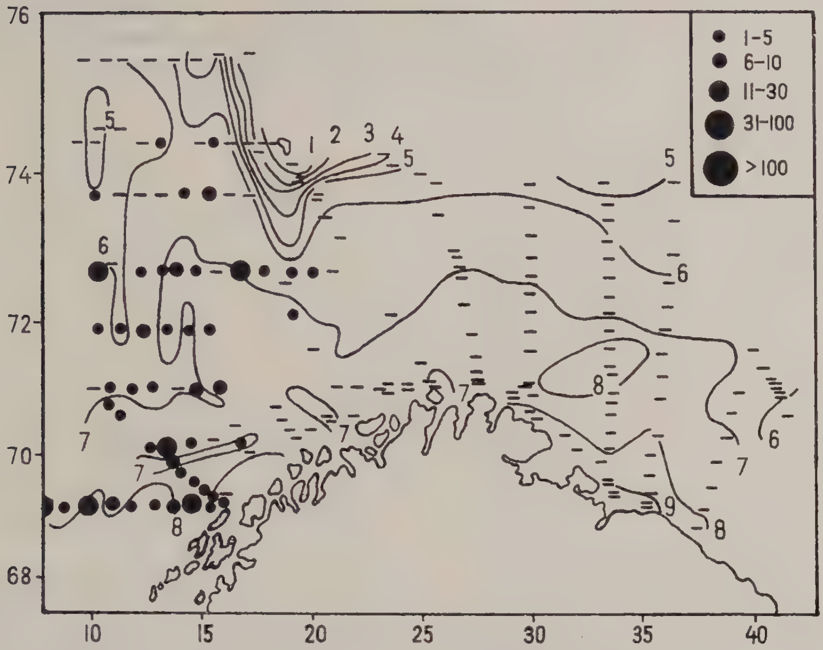
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Figure 6a. Distribution of redfish larvae according to vertical haul data (bottom to surface) with the egg-net, together with surface isotherms in June-July 1959. Key as for Figure 5a.

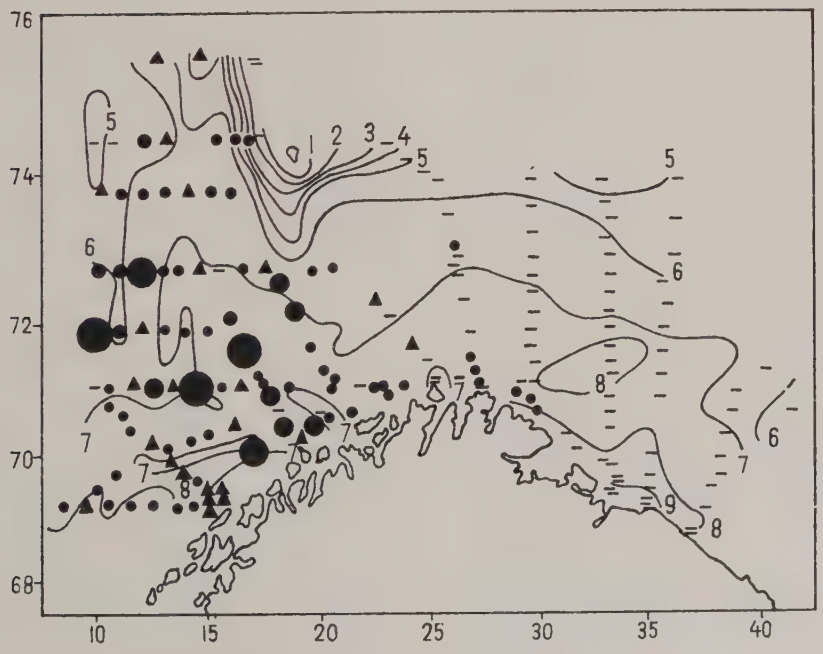
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Figure 6b. Distribution of redfish larvae according to oblique haul data (50 m to surface) with a perlon ring trawl; mesh size 3 mm; vessel circling for 10 minutes. Surface isotherms in June/July 1959. Triangles indicate presence of larvae in the catch according to egg-net data. Circles of different sizes indicate the number of larvae caught per haul.

Table 5
Sizes of redfish larvae during April/July 1959, by five-day periods (from catches taken by egg-net and ring trawl (⁰/₀))

Month	Five-day period	Length (millimetres)											Number of specimens
		6	7	8	9	10	11	12	13	14	15	16	
						Egg-net							
IV	5	13·8	79·3	6·9	–	–	–	–	–	–	–	–	29
IV	6	17·0	59·1	22·5	1·4	–	–	–	–	–	–	–	294
V	1	15·5	66·7	15·8	2·0	–	–	–	–	–	–	–	702
V	2	22·6	48·2	27·9	1·3	–	–	–	–	–	–	–	448
V	3	14·2	61·7	22·5	1·6	–	–	–	–	–	–	–	888
VI	2	1·6	28·4	20·0	12·6	16·8	9·5	8·4	3·2	–	–	–	95
VI	3	–	20·0	21·4	24·0	16·0	9·3	8·0	1·3	–	–	–	75
VI	4	0·8	6·9	10·0	26·1	23·1	18·5	10·0	3·1	1·5	–	–	130
VI	5	–	–	4·8	23·8	33·3	28·5	–	4·8	4·8	–	–	21
						Ring trawl							
VI	2	–	–	0·9	0·9	8·8	37·2	22·2	19·5	1·8	0·9	0·9	113
VI	3	–	–	4·0	16·0	8·0	28·0	20·0	16·0	8·0	–	–	25
VI	4	–	0·3	1·3	2·6	17·1	33·1	29·8	10·2	5·2	0·4	–	695
VI	5	–	–	–	5·5	8·3	25·7	33·9	18·4	6·4	0·9	0·9	109
VI	6	–	–	–	7·1	–	28·6	21·5	7·5	21·5	7·1	7·1	14
VII	1	–	–	–	–	–	33·3	33·3	–	33·3	–	–	6

and to the east of this section in July. As can be seen, egg-net and ring-trawl catches do not show quite the same picture as to the presence of larvae in a given locality. That is why, in order to obtain a more objective picture, the results of catches by the two gears are given separately.

In June 1959 redfish larvae were distributed over a large area. They were observed in the north as far as 75°N; they may have occurred further north, but the "Tunets" did not operate there. Larvae were also captured early in July in the coastal branch of the North Cape Current, but only as far as 30°E. In the first half of July larvae were not found further east.

The presence of small, 6–7 mm long redfish larvae in the egg-net catches (Table 5), suggests that liberation continued during June, especially in the first half of this month. Besides small larvae, a considerable part of the catches consisted of rather large specimens, 9–11 mm long. The longest larva found measured 14 mm. The ring trawl brought even larger specimens, of which the overwhelming majority measured 11–13 mm, and the largest 16 mm.

During April and May the redfish larvae remained below the surface and not at the surface, irrespective of the time of day. When sampling with the egg-net on a boat circling for 10 minutes, more larvae were caught, as a rule, in the 25–0 m layer than at the surface. During the operation both the nets were fastened to one wire, so they could operate simultaneously.

A similar vertical distribution to that of redfish larvae had formerly been noticed in the distribution of larvae of cod, saithe, and others. A comparison of the temperature, salinity, oxygen, and phosphate content at the surface and in the 25 m layer reveals that the temperature, salinity, and oxygen values were somewhat lower in the 25 m layer than at the surface; the phosphate content was somewhat higher.

From the above it may be concluded that redfish larvae make their first appearance in the plankton hauls in the second half of April on the north-western coast of Norway, south-west of the Kopytov area and in the eastern part of the central Norwegian Sea. Later on they are to be found further to the north and east, and in July/August they reach 76°44′N within the Spitsbergen Current and the longitude of Teriberka in the Barents Sea area.

The most intensive reproduction of redfish occurs in May; in June liberation of larvae is continued, though on a less intensive scale, in almost all areas of the Norwegian Sea. Small, recently liberated larvae of 5–7 mm length are still being encountered in August, along with the earlier liberated larvae, the latter by then reaching the length of 10–16 mm.

The young redfish of 5–10 cm and 11–15 cm occur as far east as 35°–40°E in the southern Barents Sea and in the Bear Island/Spitsbergen area.

The length composition of young redfish shows a curve with three peaks: 7–8 cm, 12 cm, and 15 cm. This is indicative of three age-groups: 1 to 3 years of age.

These investigations have allowed the areas and times of propagation and the outermost limits of distribution of the larvae and young redfish to be established. However, it has not yet been possible to distinguish accurately between the different species of the redfish larvae and young, which fact greatly hampers biological studies. Therefore, further investigations in this field should first of all be aimed at the study of the earlier stages of development of the different redfish species, in order to find the right indices for discerning he specific composition of larvae and young fish. This vill allow a more detailed knowledge of the biology of ach species to be obtained and will consequently aid n finding new areas for redfish exploitation.

Summary

The contribution is based on the material collected y the Polar Research Institute of Marine Fisheries nd Oceanography (PINRO) during 1934–55 and in 959. The data obtained on larvae and young of redish have been worked up and have resulted in the ollowing conclusions:–

1. Larvae of redfish usually appear in the plankton auls in the second half of April off the north-western oast of Norway, south-west of the Kopytov area, and n the eastern part of the Norwegian Sea. Later on hey can be found further north and east, reaching he latitude of 76°N in July-August within the Spitsergen Current and the longitude of Teriberka in the arents Sea.

2. The most intensive reproduction of redfish occurs n May; in June liberation of larvae is continued in lmost all areas of the Norwegian Sea, though less ntensively. Small, recently liberated larvae 5–7 mm in ength can still be encountered in August, together vith the earlier liberated larvae, which by then have eached a length of 10–16 mm.

3. Young redfish of 5–10 cm and 11–15 cm occur as ar east as 35°–40°E in the southern Barents Sea and n the Bear Island/Spitsbergen area.

4. The size composition of the young redfish shows a urve with three peaks (7–8 cm, 12 cm, and 15 cm) orresponding to the three age-groups of 1 to 3 yearld fish.

5. Thus, as a result of these investigations the areas nd times of propagation of redfish larvae and young ave been established; the size composition of the oung fish and some ecological features have also been lucidated.

It should, however, be understood that the methods f identification of larvae and young of redfish have ot been fully developed, a fact which makes the study f their biology more difficult. Therefore, the studies f the earlier stages of development of various redfish pecies should be continued, in order to establish some ndices for identifying the species to which the larvae nd the young belong. This will, in turn, allow more etailed knowledge of the biology of each species to be ained and will help in finding new areas for redfish xploitation.

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3.

Distribution of Redfish Larvae in the Western Barents Sea

By
JOHN CORLETT
Fisheries Laboratory, Lowestoft

Introduction

The research vessel "Ernest Holt" has worked in the western Barents Sea since 1949 and plankton hauls have been made on most cruises. No special hauls were made for redfish larvae, but many have been caught during other work, particularly during studies of the distribution of cod larvae between the Bear Island Bank and the Norwegian coast in 1952, 1957, and 1958. This paper is an account of the distribution and lengths of the larvae collected, followed by a short discussion of the related distribution of adult redfish.

Methods

The following nets have been used:–

(i) A 1 metre stramin net, towed at about 2½ knots for thirty minutes with a Kelvin tube recording the maximum depth of towing.

(ii) A 1 metre net of No. 0 bolting silk (40 meshes to the inch), non-closing, hauled vertically. A flowmeter was sometimes used but as it was not used on all the cruises considered here the actual catches are quoted: where the flowmeter was used the corrections made no difference to the pattern of distribution.

(iii) A pair of 1 metre nets joined together by a "spectacle" frame: in June 1952 the nets were made of mosquito netting of about 30 meshes to the inch.

(iv) A modified Gulf III plankton sampler as described by Bridger (1956), towed at about 5 knots and referred to as the High-Speed Tow Net (H.S.T.N.).

(v) A Hensen egg-net with silk of 60 meshes to the inch or a similar smaller net with 40 cm diameter top-ring was used on all cruises but did not catch many larvae.

The plankton samples were preserved in 2 % neutral formalin and, after sorting, the fish larvae were preserved in 70 % alcohol. Measurements were made to the nearest millimetre below and are quoted as such in the length distribution: where the mean length of a sample is quoted 0·5 mm has been added to the mean calculated from the measurements.

It was not found possible to distinguish between the larvae of *Sebastes marinus* and *S. mentella* (see Discussion). A few larvae had the pigment spot on the tail which Dr. Tåning (this section) considered to be the distinguishing feature of *S. viviparus* larvae. The presence of this spot in most larvae of *S. viviparus* has been confirmed by examination of larvae taken from ripe females of this species from the Faroes.

Distribution

1949. Sebastes larvae were collected only between 31. May and 10. June, when tows with a 1 m stramin net were made west and south of Bear Island (Figure 1). The larvae were most abundant over the deep water west of the bank in the West Spitsbergen Current and few were taken on the bank. The tows were made with different lengths of wire but the net was not a closing one, so little can be said about the depth distribution except that most larvae were caught in hauls where the net was mainly in the top 80 metres. The length distribution (Table 1), with a mean of 7·80 mm, shows that many of the larvae had been recently liberated, since at that time they are about 5 mm long. Larvae with the pigment spot on the tail were taken only at one station on the Tromsø Plateau (V in Figure 1).

1952. Between 19. and 22. June a line of stations was worked from Bear Island to the Norwegian coast using the 1 m spectacle net hauled vertically from between 400 and 100 metres (Figure 1). The numbers on the chart are the mean numbers of *Sebastes* larvae per net per station. The largest catch was in 72°34′N, 16°20′E where the temperature was 7·60°C at the surface and 4·20°C at 410 m, near the bottom. Surface

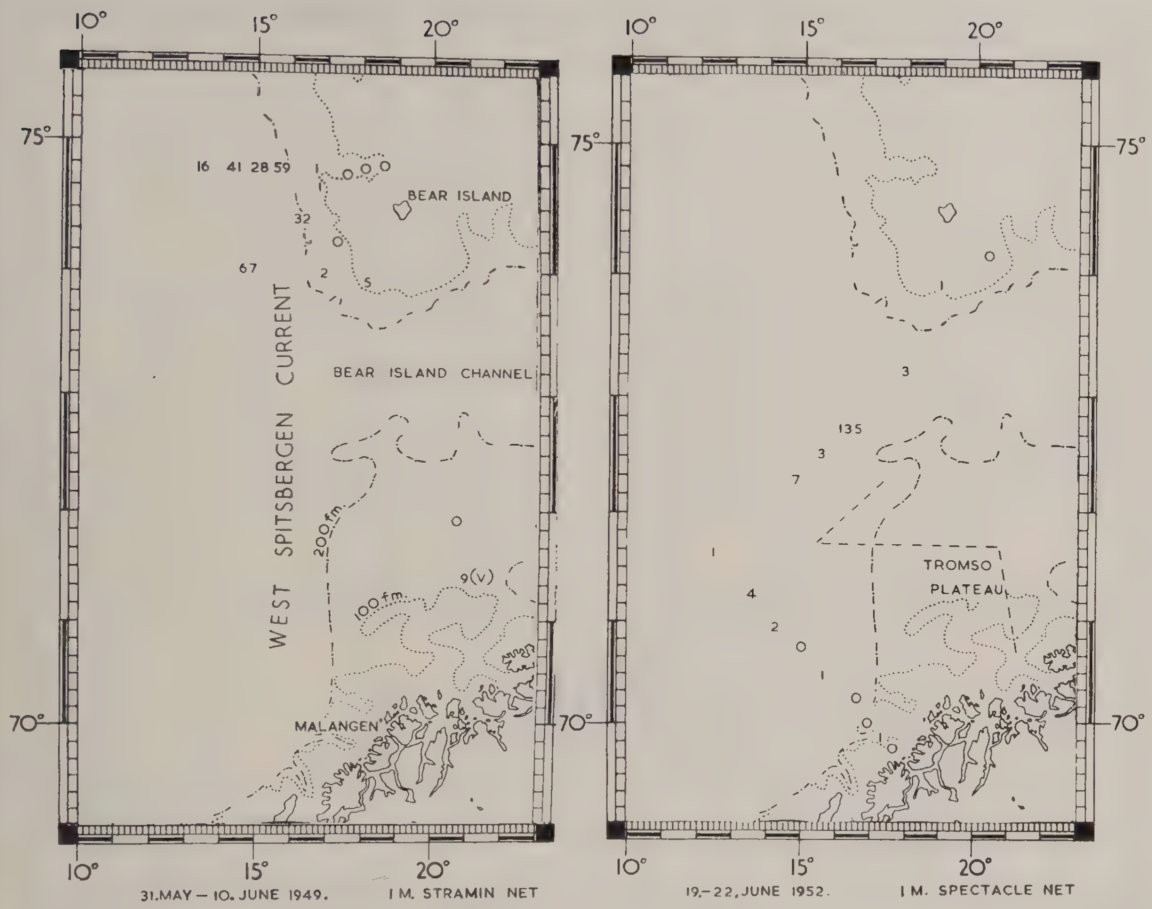
10°
15°
20°
75°
70°
16
41
28
59
32
67
2
5
BEAR ISLAND
BEAR ISLAND CHANNEL
WEST SPITSBERGEN CURRENT
200 fm.
100 fm.
9(v)
MALANGEN
31. MAY – 10. JUNE 1949.
1 M. STRAMIN NET
3
135
3
7
1
4
2
TROMSO PLATEAU
19.–22. JUNE 1952.
1 M. SPECTACLE NET

Figure 1. Redfish larvae, average numbers per net.

Table 1. Lengths of redfish larvae

Date	Locality	Net	Number measured	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Mean length (mm)	Standard deviation
				Percentage at each length (mm)															
1949																			
1/5–10/6	Bear Is.	1 m Stramin	354	1	25	35	24	11	3	<1	<1	–	–	–	–	–	–	7·80	1·15
1952																			
9–22/6	Bear Is. Channel	1 m Mosq.	338	<1	8	27	39	16	6	2	<1	<1	–	–	–	–	–	8·48	1·22
1957																			
9–30/4	Malangen	1 m Silk	35	3	63	31	3	–	–	–	–	–	–	–	–	–	–	6·84	–
/5	Bear Is. Channel	1 m Silk	66	3	36	50	9	2	–	–	–	–	–	–	–	–	–	7·20	–
5/6	Malangen	1 m Silk	19	–	16	26	32	11	11	0	5	–	–	–	–	–	–	8·45	–
9/6–3/7	Bear Is.	1 m Silk	14	–	–	–	–	–	–	–	14	29	14	21	7	0	14	14·86	–
1958																			
0/4–1/5	Malangen	1 m Silk	32	–	6	19	75	–	–	–	–	–	–	–	–	–	–	8·19	0·60
5–16/5	Bear Is.	1 m Silk																	
	Channel	H. S. Tow	189	3	8	21	41	23	3	<1	–	–	–	–	–	–	–	8·35	1·06
–2/7	Bear Is.	H. S. Tow	116	–	–	–	3	5	18	17	22	21	9	3	3	<1	–	12·31	1·78

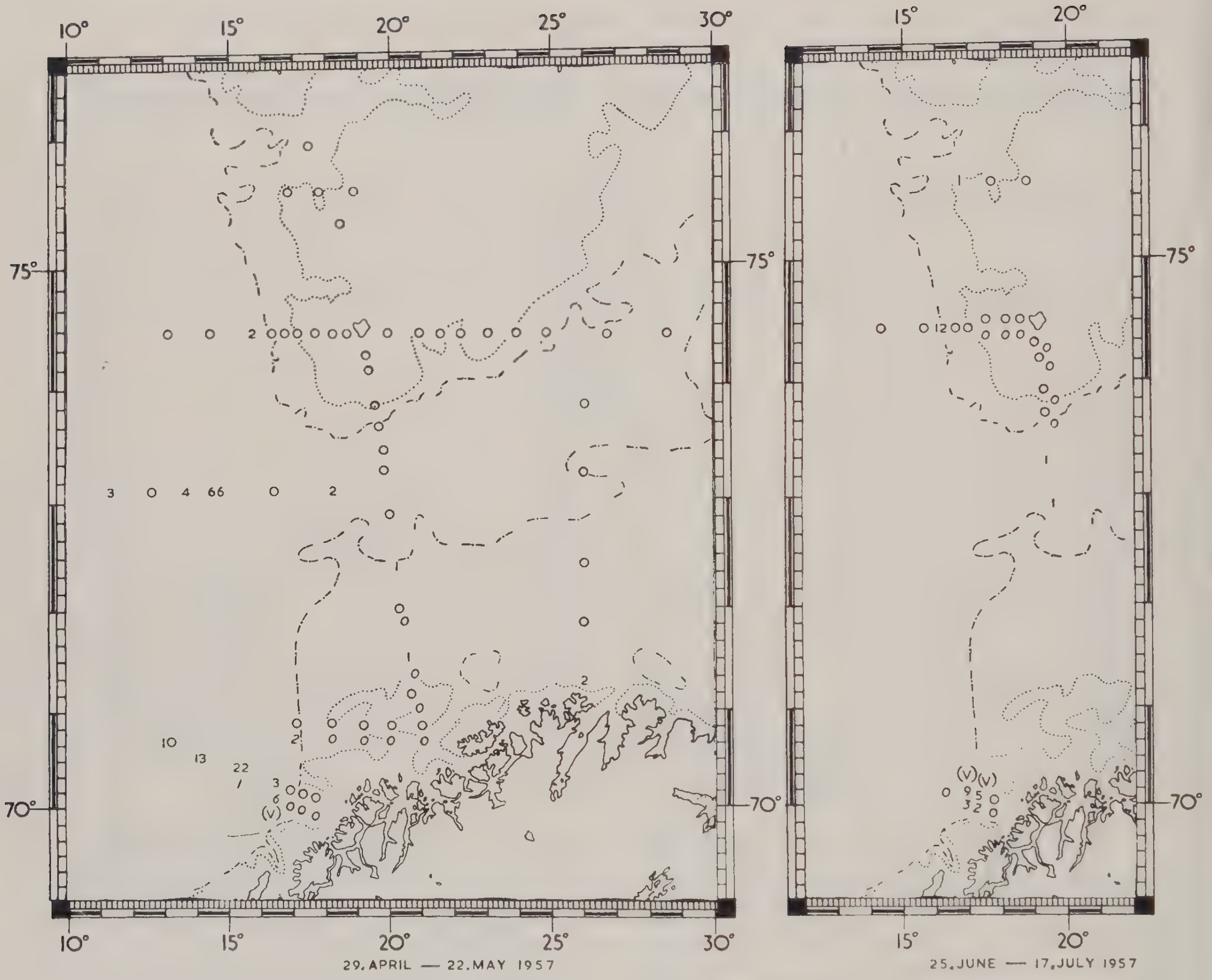

Figure 2. Redfish larvae in 1 m silk net (single or upper number) and High-Speed Tow Net (lower number).

temperatures on the lines ranged from 5·0°C in the north to 9·8°C near the Norwegian coast. The length distribution (Table 1) shows that most of the larvae were between 7 and 9 mm.

On the previous cruise, during the search for cod eggs and larvae between 23. and 25. April, 17 stations were worked northwards from the Norwegian coast with horizontal and vertical nets (dashed line in Figure 1). Cod larvae were caught at several stations but no *Sebastes* larvae were found.

1957. In late April and May the western Barents Sea was covered extensively with hydrographic sections and plankton hauls. Vertical hauls with the 1 m silk net were made at all stations, usually from 600 metres or the bottom, and 10 minute oblique hauls with the High-Speed Tow Net were made at most stations south of 72°N. Figure 2 shows the distribution of *Sebastes* larvae and it will be seen that the majority were taken in the West Spitsbergen Current west of the Norwegian coast and the Bear Island Channel. A line of stations in 79°07′N between 5°38′E and 10°E (not shown on the chart) produced no larvae. At the station in 73°02′N, 14°40′E, where 66 redfish larvae were caught, the depth was 684 metres, the temperature being 5·49°C at the surface, 4·34°C at 400 metres and 2·05°C at 636 metres. The hydrographic data for this cruise and the following one are in M.A.F.F. (1957), which shows that the surface temperatures at the stations on the line between the Norwegian coast and Bear Island and westwards, worked between 29. April and 9. May, were between 4·6° and 6·3°C. The larvae were mostly in the 6 mm and 7 mm groups (Table 1) and so had been recently liberated. Only one larva had the caudal pigment spot and that was taken off the Norwegian coast near Malangen.

On the next cruise in late June and early July some of the stations worked on the previous cruises were epeated (Figure 2). The High-Speed Tow Net tows were for 20 minutes on this cruise. The section in 79°07′N (not in chart) again produced no larvae. Few *Sebastes* larvae were caught and they were in two groups. The twelve caught west of Bear Island ranged n size from 12 to 18 mm (Table 1) and had probably been carried there from an earlier spawning further south. Off Malangen the 19 larvae were smaller, including seven with the caudal pigment spot, suggesting more recent spawning. The surface temperatures were 7·2°C off Malangen and 6·3°C at the station west of Bear Island where the larvae were caught.

The sections worked in May were repeated in August (except that west of the Bear Island Channel) but no *Sebastes* larvae were caught.

1958. In late April and May vertical hauls from 100 metres with the 1 m silk net and 20 minute tows at about 100 metres with the High-Speed Tow Net were made between the Lofoten Islands and the Bear Island Channel (Figure 3). As in previous years the largest catches of *Sebastes* larvae were over deep water in the West Spitsbergen Current. The mean length of the larvae was 1 mm greater than at the same time in 1957 (Table 1), which suggests that the spawning was earlier in 1958: in the time after spawning the larvae would have drifted northwards. The surface temperature decreased from 7°C off the Lofotens to 5°C in the Bear Island Channel.

On the following cruise in late June and early July the same nets were used, the 1 m net hauls being made from the bottom or 600 metres: on the westernmost station west of Bear Island the 31 shown in Figure 3 is the mean of three tows between 20 and 35 metres. The distribution of larvae (Figure 3) is similar to that in June–July, 1957 (Figure 2), except that fewer were caught off Malangen in 1958. More larvae were caught in the tow net west of Bear Island and the length distribution has a wide range from 8 to 17 mm, with the peak between 10 and 13 mm. This suggests a long

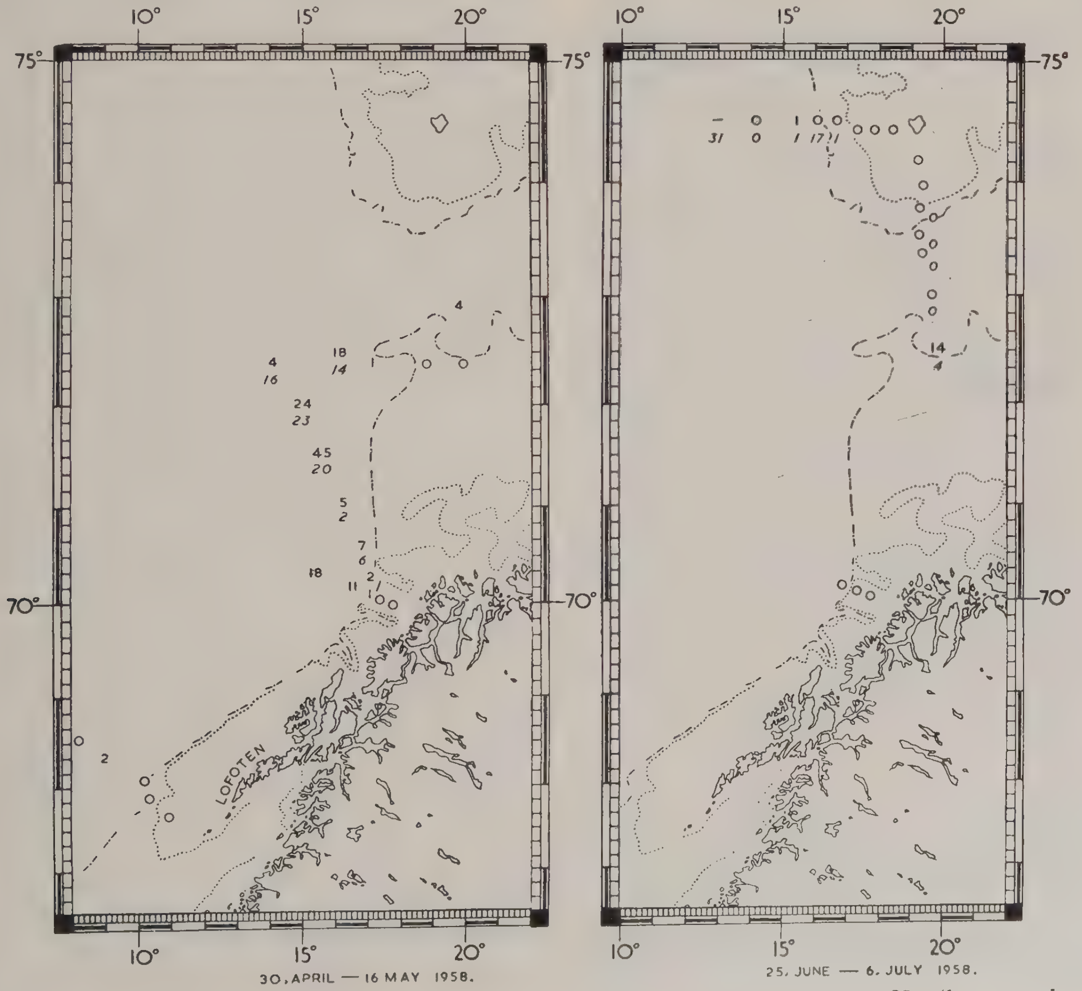

Figure 3. Redfish larvae in 1 m silk net (single or upper number) and High-Speed Tow Net (lower number).

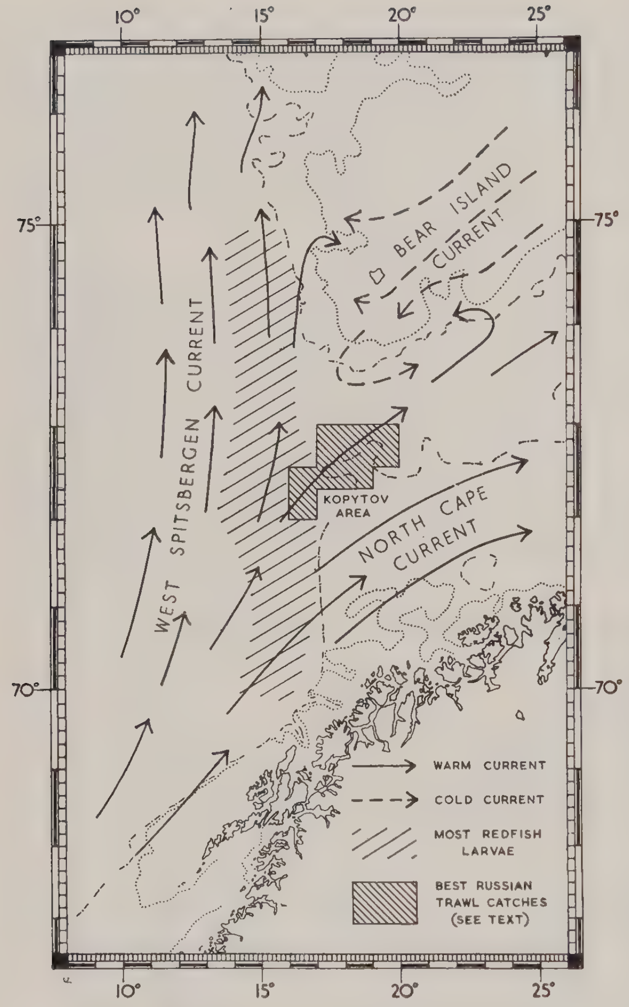

Figure 4. Surface currents, redfish larvae, and spring trawling area.

spawning season, no spawning at the time and place of the collections, and transport of the larvae in the currents from a more southerly spawning area. The surface temperature was about 7°C west of Bear Island, 6°C in the Bear Island Channel and 9°C off Malangen.

No larvae were found on cruises in March when hauls were made off Malangen, or in August south of Bear Island and in 77°N off West Spitsbergen.

Discussion

Baranenkova *et al.* (1956) give charts of the distribution of *Sebastes* larvae over a large area of the Norwegian Sea and western Barents Sea, but give no information on dates or numbers or lengths of larvae. They include the area of the present study as one where larvae were caught at most stations occupied.

Figure 4 shows the relation between the distribution of the larvae caught by the "Ernest Holt" and the main current systems. Most of the larvae are in the West Spitsbergen Current off the edge of the continental shelf. From this it seems that the spawning area extends from the Norwegian coast south of Malangen, to west of Bear Island, probably varying in extent from year to year. Most spawning occurs between 72° and 73°N. From the spawning area the larvae will be carried northwards towards Spitsbergen and northeastwards towards Hope Island, and indeed the young bottom stages have been found in autumn on the West Spitsbergen banks and on the Bear Island and Hope Island banks (Trout, this volume).

From the sizes of larvae caught in late April in 1957 and 1958 (Table 1) it appears that spawning began towards the end of April. Some larvae of 6 and 7 mm were caught at the end of May and until mid-June in 1949, 1952 and 1957, showing that spawning was continuing. No newly liberated larvae were found in July in the areas sampled, which did not include the main spawning area. These observations suggest that the main spawning takes place between 20. April and 20. June.

The area and time of the largest catches of small larvae fit well with the Soviet spring trawl fishery for redfish in the "Kopytov" area, which has been described by Travin (1957), Surkova (1957), Adrov (1957), and Baranenkova (1957). The area of best catches in that fishery in 1952, 1954 and 1956, shown in Figure 4, is taken from charts in the papers by Adrov and Baranenkova. The main fishing area is at the edge of the shelf, close to the centre of distribution of the larvae. According to Travin the best fishing in the Kopytov area takes place from April to June, with the heaviest catches usually in May though occasionally in April. All the Russian authors quoted here agree that the bulk of the catch in the Kopytov area consists of *Sebastes mentella* with some *S. marinus,* while Baranenkova's charts show that more *S. marinus* are caught further south off the Norwegian coast, from Malangen eastwards into the Barents Sea. *S. viviparus* are caught in the shallower water of the Malangen bank. Surkova says that catches of *S. mentella* in the Kopytov area are 70–90 % males and "females predominate in the catches during February and March, i.e. up to the beginning of the intensive fishing season and in June after the fishing has ceased. They do not form dense and permanent concentrations in the Kopytov area." Both Travin and Surkova say that no spawning area of redfish has been found, although Surkova says that mature females with larvae have been found in the area in April and May. However, the evidence presented in this paper points to the fact that there is a spawning area of redfish in the Kopytov area, and it is suggested that the absence of females from the trawl catches is a result of their behaviour at spawning time. Probably they are pelagic over the Kopytov area and over the deep water to the west and so are not caught by the bottom trawls – although there would seem to be no reason why the males and females should be together at the time of liberating the larvae.

It is unfortunate that it has not been found possible so far to distinguish between the larvae of *Sebastes mentella* and *S. marinus*, but the evidence from the trawl catches suggests that larvae of both species are present in the larval catches, with *S. mentella* probably in larger numbers. If the larvae of *S. viviparus* can be distinguished by the caudal pigment spot, then the little information presented here is confirmed by the catches of *S. viviparus* reported by Baranenkova from the coastal banks. It also seems that spawning of *S. viviparus* is later than that of the other species, since the newly liberated larvae were found mostly in June.

Hydrographical conditions in the Kopytov area are discussed by Adrov (1957), and data for the plankton stations discussed in this paper are given in M.A.F.F. (1949, 1952, and 1957). Surface temperatures in the part of the West Spitsbergen Current between Malangen and Bear Island from late April to late June are usually between 5·0° and 7·5°C. The temperatures on the bottom between 350 and 450 metres are between 3° and 5°C in the Kopytov area in May, and Adrov states that the optimum temperature for the congregation of redfish in the area is 4° to 5°C. Temperatures between 4° and 5°C occur not only on and near the bottom but throughout about 150 metres of the water column over the Kopytov area and over the deeper water to the west where liberation of larvae takes place.

Summary

The distribution of *Sebastes* larvae caught in various plankton nets between the Lofoten Islands and the Bear Island Bank in 1949, 1952, 1957, and 1958 is presented.

Most larvae are caught over deep water to the west of the continental shelf.

From the size distribution of the larvae it appears that liberation of larvae takes place throughout the area. The spawning area may vary in extent from year to year, but it is mostly between 72°N and 73°N. Most spawning occurs between 20. April and 20. June.

This area and time coincide with the large Soviet trawl fishery for redfish in the Kopytov area on the edge of the shelf. This fishery is mostly for male *Sebastes mentella*. It is suggested here that the females, when spawning, are in the same area but in mid-water.

Temperatures in the Kopytov area are between 3° and 5°C on the bottom in May, and surface temperatures in the area of larval concentrations are between 5° and 7·5°C between late April and late June.

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4.

Redfish Larvae from Ocean Weather Station "A" in 62°N, 33°W

By
JOHN CORLETT
Fisheries Laboratory, Lowestoft

British Ocean Weather Ships have been taking their turn with ships of France, the Netherlands, and Norway in manning Ocean Weather Station "A" since 1955. While on station the British ships make plankton hauls weekly, and this note concerns the redfish larvae from samples taken in 1955, 1956, 1957, and 1958.

The net used is made of No. 3 silk (60 meshes to the inch) and has a conical canvas top-piece with upper ring 40 cm diameter and lower ring 50 cm diameter. It is hauled vertically from 100 metres to the surface and theoretically filters 12·5 m^3 of water in each haul. It is a good net for collecting copepods and other small zooplankton but will catch only the smaller and less active fish larvae. The hauls are usually made in the dark but this is not always possible in summer. The centre of the ship's station is 62°N, 33°W and most of the hauls are made within 10 miles of this position. This is on the edge of the area considered by Henderson (this section, p. 216).

The catch is preserved in 2 % formalin and the larvae have been measured to the nearest millimetre below. The mean lengths quoted have 0·5 mm added to the value calculated from the measured lengths. None of the larvae had the caudal pigment which was said by Dr. Tåning (this section) to distinguish the larvae of *Sebastes viviparus* in the eastern Atlantic and by Templeman and Sandeman (this volume, p. 241) to distinguish *S. mentella* in the western Atlantic.

Table 1 gives the number and lengths of larvae caught in all hauls in April, May and June. Only one haul was made in June, and no *Sebastes* larvae were caught in several hauls in July 1955 and 1957. Surface temperatures were not recorded regularly by the ships on this station; they were between 5·8°C on 29. April and 7·2°C on 13. May in 1955, and between 6·6°C on 16. May and 7·8°C on 31. May in 1957.

The most that can be said from the scanty data is that liberation of larvae takes place between mid-April and the end of May, and more larvae were caught in 1956 than in 1955. They were probably the larvae of *Sebastes marinus*.

Table 1
Redfish larvae from Ocean Weather Station "A"

Year	Date	Day or Night	Number caught	Length in mm									Mean length, mm
				6	7	8	9	10	11	12	13	14	
1955	7. Apr.	N	0	–	–	–	–	–	–	–	–	–	–
	20. Apr.	N	0	–	–	–	–	–	–	–	–	–	–
	28. Apr.	D	0	–	–	–	–	–	–	–	–	–	–
	5. May	D	4	–	1	1	2	–	–	–	–	–	8·75
	12. May	D	2	–	–	–	2	–	–	–	–	–	9·50
1956	19. Apr.	N	17	–	2	15	–	–	–	–	–	–	8·38
	26. Apr.	N	46	1	13	30	1	–	–	–	–	–	8·19
	17. May	D	4	–	1	2	1	–	–	–	–	–	8·50
	24. May	D	5	–	–	1	0	2	1	1	–	–	10·70
	1. June	D	4	–	–	–	–	2	2	–	–	–	11·00
1957	19. Apr.	N	6	1	4	1	–	–	–	–	–	–	7·50
	25. Apr.	N	3	–	1	2	–	–	–	–	–	–	8·17
	3. May	N	4	–	–	4	–	–	–	–	–	–	8·50
	16. May	N	4	–	–	2	1	–	–	–	–	–	8·83
	29. May	N	12	–	1	3	3	3	1	0	0	1	9·92
1958	6. May	N	5	–	–	5	–	–	–	–	–	–	8·50

5.

Summer Surface Distribution of Redfish Larvae in ICNAF Subarea 4, 1954—1955

By

L. R. DAY

Fisheries Research Board of Canada, Biological Station, St. Andrews, N. B.

Surveys for fish eggs and young fish were carried out in the Bay of Fundy, Scotian Shelf, and Gulf of St. Lawrence areas of north-west Atlantic waters (ICNAF Subarea 4) in 1954 and 1955 from the Fisheries Research Board of Canada, Biological Station at St. Andrews, N.B. This paper is based on the collections of larvae of redfish (*Sebastes marinus* L.) and deals with their distribution, abundance, and size. Dannevig (1919), Jean (1955), and Steele (1957) have published results of previous redfish larval collections in Subarea 4.

Materials and Methods

Collections were made with a 1-metre, high-speed net (Gauld and Bagenal, 1951) towed at 4 to 5 knots for 10 to 15 minutes at the surface (high-speed tow) and a 1-metre, conventional-type net towed at 0 to 2 knots for 5 minutes at 20, 10, and 0 metres (3-level tow). Both types of nets had equal straining surface area and were made of grit gauze of 23 meshes per inch. A map of the area investigated is shown in Figure 1.

1954 surveys were as follows:–

(1) *"Mallotus" Plankton Surveys* No. 1, 9. to 24. August and No. 2, 25. August to 14. September. Thirty-six inshore stations were occupied off the Nova Scotian coast between Canso and Yarmouth on each survey (Fig. 1).

(2) *"Sackville" Cruise* No. 23, 18. August to 4. September. Forty-one offshore stations were occupied in the Bay of Fundy off Nova Scotia, and in the Gulf of St. Lawrence (see cruise lines I to XII, inclusive, of Fig. 1).

(3) *"Sackville" Cruise* No. 25, 8. to 10. October. Eight offshore stations were occupied in the Bay of Fundy and off south-western Nova Scotia (see cruise lines I to III, inclusive, of Fig. 1).

1955 surveys were as follows:–

(1) *"Pandalus" Cruise,* 21. April to 4. May.
"Mallotus" Cruise, 14. to 27. May.
"Cowie" Cruise, 11. to 18. June.
Twelve to 14 inshore stations (Fig. 1) were occupied from Grand Manan, N.B., in the Bay of Fundy, along the Nova Scotian coast, to Northumberland Strait, to Shippegan Island, N.B., or to Miscou Island, N.B., in the Gulf of St. Lawrence. Only high-speed tows were made.

(2) *"Sackville" Cruise* No. 26, 12. June to 19. July. Sixty-two offshore stations were occupied in the Bay of Fundy, off Nova Scotia, and in the Gulf and Estuary of the St. Lawrence (see cruise lines I to XIV, inclusive, of Fig. 1).

(3) *"Sackville" Cruise* No. 27, 14. August to 4. September. Forty-one offshore stations were occupied in the Bay of Fundy, off Nova Scotia, and in the Gulf of St. Lawrence (see cruise lines I to XII, inclusive, of Fig. 1).

Larval Distribution, Abundance, and Size

Distribution

1954: The distribution and abundance of larvae taken in the August to September cruises are shown in Figure 2A. Thirty-five of the total of 52 larvae were taken off south-western Nova Scotia, 32 in the vicinity of Roseway and LaHave Banks. Five larvae were taken in the deep waters at the entrance to the Bay of Fundy, 6 in the deep waters between Sable Island and Banquereau banks, while 5 were taken along the deep-water Laurentian Channel in the Gulf of St. Lawrence. Of the 14 larvae taken during the two inshore "Mallotus" cruises, 6 and 8 larvae respectively were taken in the Roseway Bank area. In October a single larva was taken at the entrance to the Bay of Fundy in an offshore cruise covering the entrance to the Bay of Fundy and south-western Nova Scotia (see Sections I to III, inclusive, of Fig. 1).

1955: In the inshore waters between the Bay of Fundy and Gulf of St. Lawrence between April and June, only 25 larvae were taken. These were taken in the Gulf of St. Lawrence between Magdalen and Miscou Islands near mid-June (Fig. 2B). In the offshore waters from June to July a total of 570 larvae were taken (Fig. 2C). Greatest numbers (283) were

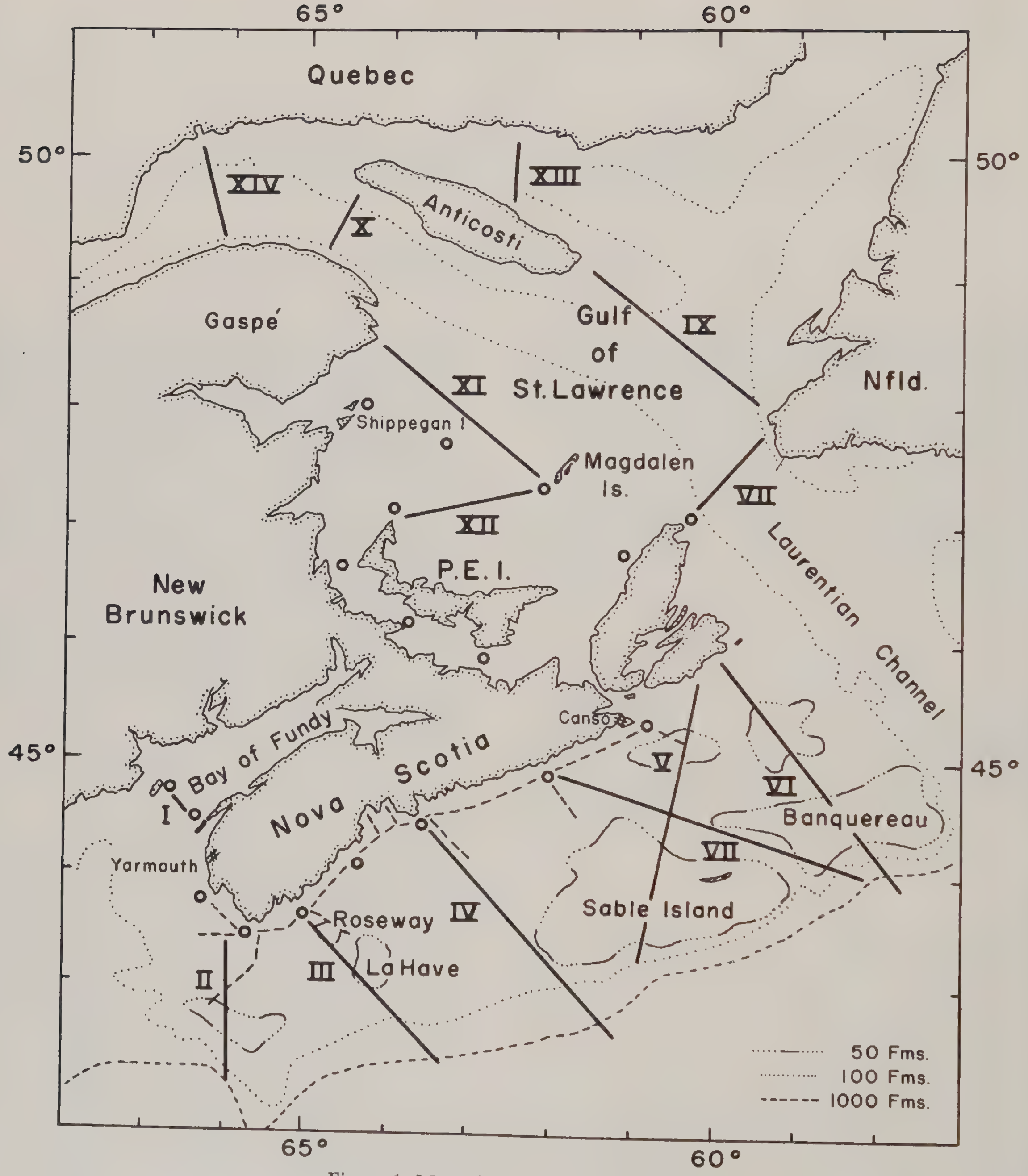
65°
60°
50°
50°
45°
45°
Quebec
XIV
X
XIII
Anticosti
Gaspé
Gulf
of
St. Lawrence
IX
XI
Nfld.
Shippegan I
Magdalen
Is.
VII
XII
P. E. I.
Laurentian
Channel
New
Brunswick
Bay of Fundy
Canso
V
VI
Nova
Scotia
Banquereau
I
Yarmouth
VII
Sable Island
Roseway
IV
II
III
La Have
50 Fms.
100 Fms.
1000 Fms.
65°
60°

Figure 1. Map of the area investigated.
Solid lines = "Sackville" cruises. Dashed lines = "Mallotus" plankton surveys
Open circles = "Mallotus", "Pandalus", and "Cowie" stations.

from the deep waters in the north-eastern part of the Nova Scotian banks (sections IV to VII, inclusive). A tow on Banquereau Bank took 127 larvae. Of the remainder, 215 larvae were taken in the deep waters of the Gulf of St. Lawrence. From August to September, 40 larvae were taken, 34 between Anticosti Island and Gaspé. None were taken on the south-western Nova Scotian banks (Fig. 2D).

Abundance

Throughout the area investigated larvae were most abundant (5·4 per tow) in the offshore areas in the

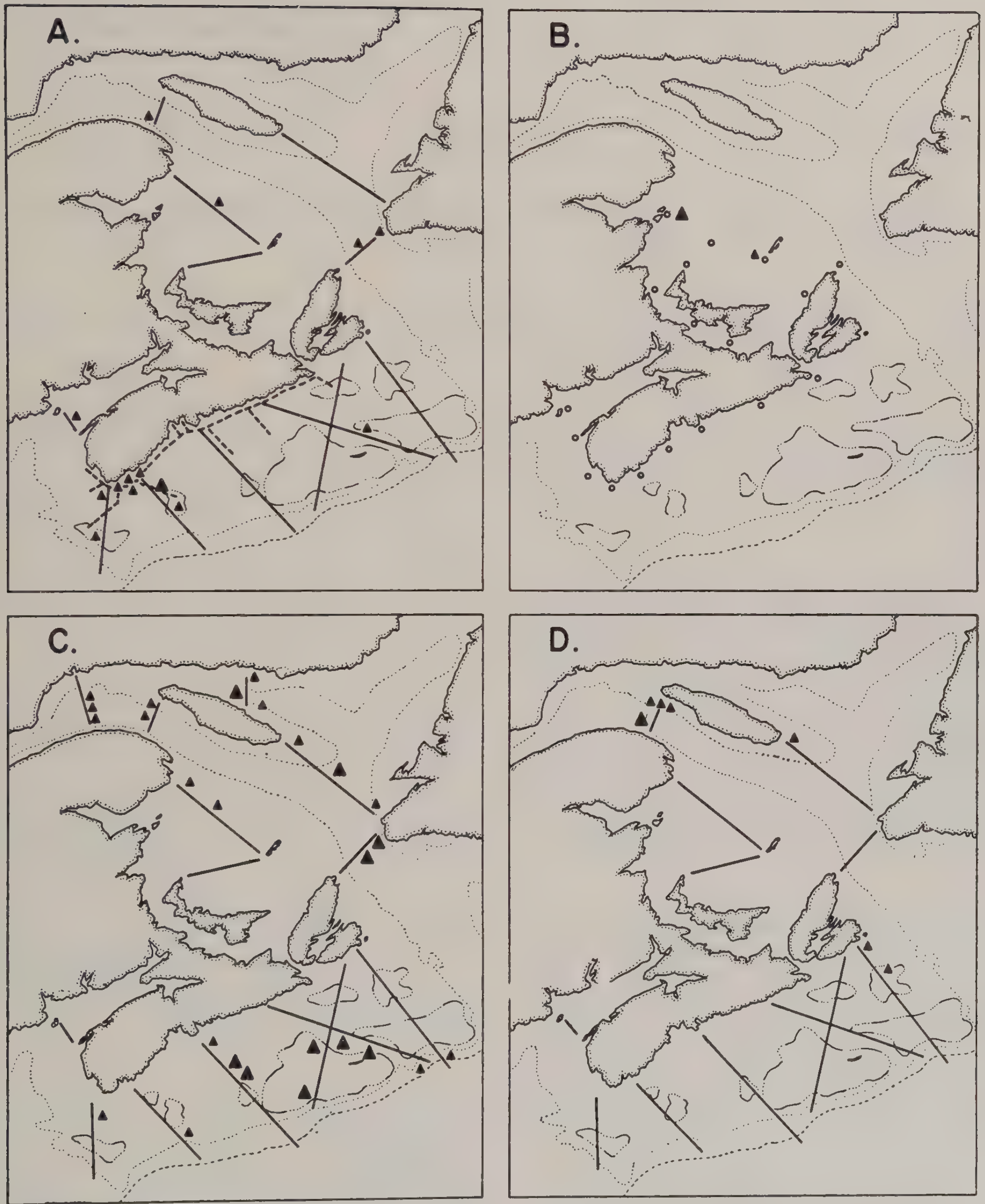

Figure 2. Distribution and abundance of redfish larvae collected in the surface waters of ICNAF Subarea 4 (Bay of Fundy, Nova Scotian banks, and Gulf of St. Lawrence).
A. August–September, 1954. C. June–July, 1955. B. April–June, 1955. D. August–September, 1955.
Large triangles = more than 10 larvae. Small triangles = less than 10 larvae.

Table 1
Catch per tow of redfish larvae taken in ICNAF Subarea 4 in 1954 and 1955

Cruise	Number of tows		Number of Larvae	Number of Larvae/tow
	High-speed	Three-level		
1954				
Aug.–Sept. (inshore)	72	72	14	0·1
Aug.–Sept. (offshore)	35	31	37	0·6
Oct. (offshore)	–	8	1	0·1
1955				
Apr.–June (inshore)	39	–	25	0·6
June–July (offshore)	52	54	570	5·4
Aug.–Sept. (offshore)	28	36	40	0·6

Table 2
Size range of redfish larvae taken throughout ICNAF Subarea 4 in 1954—55. Size was measured as total length in mm

(Numbers of larvae in brackets)

Sections Period	Bay of Fundy I	Nova Scotian banks II	III	IV	V	VI	VII
1954							
Aug.–Sept.	6–7 (5)	7–14 (3)	5–16 (32)	– (0)	– (0)	– (0)	7–10 (6)
Oct.	19 (1)	–	–	–	–	–	–
1955							
June–July	– (0)	11–12 (2)	8 (1)	6–10 (67)	5–9 (39)	6–9 (131)	6–16 (113)
Aug.–Sept.	–	–	–	– (0)	– (0)	6–9 (2)	– (0)

Sections Period	Gulf of St. Lawrence VIII	IX	X	XI	XII	XIII	XIV
1954							
Aug.–Sept.	9–14 (3)	– (0)	19 (1)	15 (1)	– (0)	–	–
1955							
Apr.–June	–	–	–	7–21 (25)	–	–	–
June–July	7–16 (57)	6–15 (97)	7–8 (19)	6–7 (13)	– (0)	4–15 (17)	6–9 (12)
Aug.–Sept.	– (0)	9–13 (4)	6–10 (34)	– (0)	– (0)	–	–

June to July period (Table 1). Other offshore cruises took 0·6 larva per tow except the October cruise where only 0·1 larva per tow was taken in the Bay of Fundy and on south-western Nova Scotian banks. The inshore cruise in the spring of 1955 took 0·6 larva per tow. This was due to the capture of 25 larvae in 2 tows in mid-June between Magdalen and Miscou Islands in the Gulf of St. Lawrence at a time when spawning is reportedly at its peak (Steele, 1957; Jean, 1955).

Size

The range in total length of the larvae taken in 1954 and 1955 was from 4 to 19 mm (Table 2). The June and July period provided the greatest abundance of recently hatched (5–8 mm) larvae both on the Nova Scotian banks and in the Gulf of St. Lawrence. Comparison of sizes suggests that spawning off south-western Nova Scotia is later than in the Gulf of St. Lawrence. However, spawning does occur in all parts of the area investigated as late as the August to September period. Spawning off south-western Nova Scotia apparently does not extend into October.

Summary

1. Six hundred and eighty-seven redfish larvae were collected in inshore and offshore waters in the Bay of Fundy, off Nova Scotia, and in the Gulf of St. Lawrence from August to October in 1954 and from April to September in 1955.

2. In late summer of 1954 larvae were distributed mainly off the south-west coast of Nova Scotia, while during the same period in 1955 they were found mainly between Gaspé and Anticosti Island in the Gulf of St. Lawrence.

3. In the spring of 1955 larvae were found only between Magdalen and Miscou Islands.

4. In 1955 larvae were particularly well distributed throughout the area investigated in June and July (5·4 per tow compared with 0·1 to 0·6 per tow for other seasons in the two years). By the August to September period, larvae were restricted mainly to the Gaspé-Anticosti area with some off the north-eastern part of the Nova Scotian banks.

5. Comparison of numbers and lengths of larvae by seasons and areas confirms that spawning is heavy in the June to July period in the north-east portion of the Nova Scotian banks and in the Gulf of St. Lawrence, but may be later in the waters off Nova Scotia and in the Bay of Fundy. Spawning extends through to the August to September period in all areas sampled.

6. Larvae at the surface were most abundant along the Laurentian Channel and over the deep waters of the offshore Nova Scotian banks.

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6.

The Fry of *Sebastes* in Icelandic Waters and Adjacent Seas*)

By

HERMANN EINARSSON
Atvinnudeild Háskólans, Reykjavík, Iceland

Summary

1. The paper is based on stramin net material collected by Danish and Icelandic research ships between 1903–1939 and 1948–1952, from 1,787 stations situated mainly in Icelandic waters and the Irminger Sea. Echo-records made during 1954–1958 from the area south and west of Iceland were examined. Plankton Indicator samples, taken in the Irminger Sea in late May to early June, 1955, were studied. The stomach contents of young stages of *Sebastes marinus* were investigated.

2. For the separation of the fry of *S. marinus* and *S. viviparus,* Tåning's criteria were used, i.e. the black tail spot in the small individuals and the differences in head armature in the larger specimens. Photographs of the differences are given in Plates I and II. No tail spots were observed in the *S. marinus* fry, and no difficulties were encountered in the separation of the two species in Icelandic waters.

3. Distribution charts were prepared for each month April–September for Icelandic waters and for July and August for the Irminger Sea.

4. Photographs of selected samples of echo-records from the years 1954–1958 are given in an appendix. Plankton collections support the view that the traces in 5–30 m depth were mainly due to the presence of *S. marinus* larvae.

5. The echo-traces could perhaps be evaluated quantitatively. According to the results discussed large numbers of *S. marinus* larvae were present in the Irminger Sea in 1954, 1955, and 1957, rather few in 1956 and very few in 1958. In the area south of Reykjanes which was investigated in 1956–1958, the larvae were abundant in 1956, few in 1957, and very few in 1958. 1958 was an extremely poor year in both areas.

6. Detailed measurements of *marinus* larvae are given in an appendix. During May and June the lengths lay within the narrow range of 5 to 15 mm, with average sizes 9·29 and 7·63 mm respectively. In July the range increased very rapidly upwards to 38 mm and in August to about 60 mm. The average size for July was 20·20 mm and for August 24·95 mm. Although a slight indication of modality was observed, it is thought that all the young stages of *Sebastes* caught by the stramin net during summer belonged to the 0-group. It is suggested that food conditions may explain the sudden increase in growth-rate in July. The spawning seems of long duration, since small larvae, down to 7 mm, were found as late as July.

7. The size variations indicate a strong effect of environmental factors on the rate of growth in different years.

8. It is pointed out that the extrusion of young *S. marinus* occurs mainly outside the 1,000 m contour. Although the temperature requirements postulated by Tåning (3–8·5°C in 200–500 m depth) are fulfilled, fry may be absent or very scarce. This is supported by hydrographic data. An alternative hypothesis is postulated.

9. Analyses of Plankton Indicator samples from 2 m, 15 m, and 30 m depths at 60 stations in the Irminger Sea are given in an appendix. The following communities were identified and characterized: (a) The Mixed *Calanus* Community, (b) The Pure *Calanus* Community, (c) The *Calanus/Thysanoessa* Community, with a slope phase and an oceanic phase, (d) The Arctic *Calanus hyperboreus* Community. The young stages of

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*) This paper was presented at the ICES–ICNAF Redfish Symposium, Copenhagen Oct. 1959, in two parts, entitled:

Doc. E. 3. "Distribution, Abundance and Size of Young Stages of *Sebastes* in Icelandic Waters and Adjacent Seas"
and
Doc. E. 13. "On the Environment of the *Sebastes* Larvae in the Irminger Sea".

Now published in: Rit Fiskideildar, 2(7), title as above.

Sebastes marinus were exclusively confined to the *Calanus/Thysanoessa* Community.

10. The results of the zooplankton studies are compared with the investigations of Gillbricht and Joseph, made in the Irminger Sea in 1955. The conclusions are thought to be mutually confirmative.

11. Although adult calanoids and euphausids seem to feed on decaying matter, live phytoplankton seems to sustain a great wealth of juvenile stages of invertebrates, which serve as food for the fish fry. Annual or monthly variations in the location and onset of phytoplankton production are thought to be the main factor governing the size of the year-brood of *Sebastes marinus,* and the displacing of the production centre in 1958 to the shelf waters, as shown by Mrs. Thorđardóttir, may explain the paucity of *Sebastes* fry in that year.

12. The young *Sebastes* are selective feeders. Specimens, 8–14 mm in length, caught in the Irminger Sea in May, feed mainly on juvenile gastropods (*Spiratella* sp.) but also on copepod eggs and crustacean eggs of a similar size (about 150 μ). The gill rakers begin to develop at about 15 mm in length and the larvae retain their ability to filter this size category of organisms to about 30 mm. Samples from the middle of August showed them to feed exclusively on copepod eggs. Then they begin to take larger food items exclusively, copepodites, small copepods and even adult euphausids. Even small specimens may occasionally swallow surprisingly large food items. It is concluded that the young *Sebastes* depend largely upon the propagation of copepods in July and August, and an onset of copepod spawning in July may explain the sudden increase in growth of the larvae.

13. The fry of *Sebastes marinus* account for about 90 % of the fish fry caught in the upper layers of the Irminger Sea. Accompanying species of the macroplankton are discussed. It is pointed out how closely *Sebastes marinus* and *Thysanoessa longicaudata* agree in distribution.

14. Because of their relatively simple nature, it is thought that further studies of the *Sebastes marinus* larvae may contribute towards helping to elucidate the more intricate problems in coastal waters.

15. Distribution charts for the months April–September are given for the fry of *Sebastes viviparus.* It is a boreal "spawner", breeding inside the 200 m depth contour off the south and west coast of Iceland. The breeding intensity is very low. The "spawning" begins in May, gathers momentum in June, and reaches its peak in the beginning of July. At the peak about 20 specimens were caught per 30 minutes in positive hauls and the survey averaged between 3–4 specimens per station. The growth of the young stages is extremely slow, the average increase in size being about 3 mm from May to August.

7.

Recent Danish Investigations on the Distribution of Larvae of *Sebastes marinus* in the North Atlantic

By

VAGN KR. HANSEN and K. P. ANDERSEN

Danish Institute for Fishery and Marine Research, Charlottenlund

Introduction

Since 1947 the Danish plankton investigations in the North Atlantic have, to a great extent, been carried out with one main purpose: to investigate the biology and distribution of the fry of *Sebastes*. It was Dr. Å. Vedel Tåning's plan to work up the very great material of *Sebastes* fry collected in these years in order to continue and round off the work and ideas published in his well known paper of 1949. Unfortunately other tasks prevented Dr. Tåning from working on the biology of *Sebastes* fry. He succeeded mainly in studying taxonomic problems.

The present authors intend to outline only parts of the abundant *Sebastes* material collected since 1947. There has been too little time to treat the material as thoroughly as it merits. Yet it is thought fitting to present a preliminary report for this symposium.

Material and Methods

The present material was collected with a 2 m ring-net (stramin net). Only in a few cases was a high-speed tow net used. Unless otherwise noted, the catches listed below refer to the 2 standard hauls, which were taken simultaneously.

Haul I, 100–50–25 m wire, towed for 10 min. at each depth.

Haul II, 200–150–125 m wire, towed for 10 min. at each depth.

The upper net was fished for 30 min. at about 22–5 m, the lower one at about 43–22 m depth. In no cases were closing nets used.

With the exception of the year 1947 the material has been taken from four different sections:–

1. A section from the Shetlands to the Faroes.
2. A section from the Faroes to East Greenland along 62°N Lat. (the 62° section).
3. The sections in the Davis Strait (Cape Farewell to Hamilton Inlet and northwards).
4. Figure 1 shows the northern part of the section from Cape Farewell south-eastwards to about 57°30′N, 40°00′W. The remainder of this section, from the position given to Ireland, is not shown as no *Sebastes* were caught there.

As the western part of the 62° section is the only area from which a really large amount of material is available, only a part of this material (from 1950 and 1957) has been treated thoroughly and statistically at present.

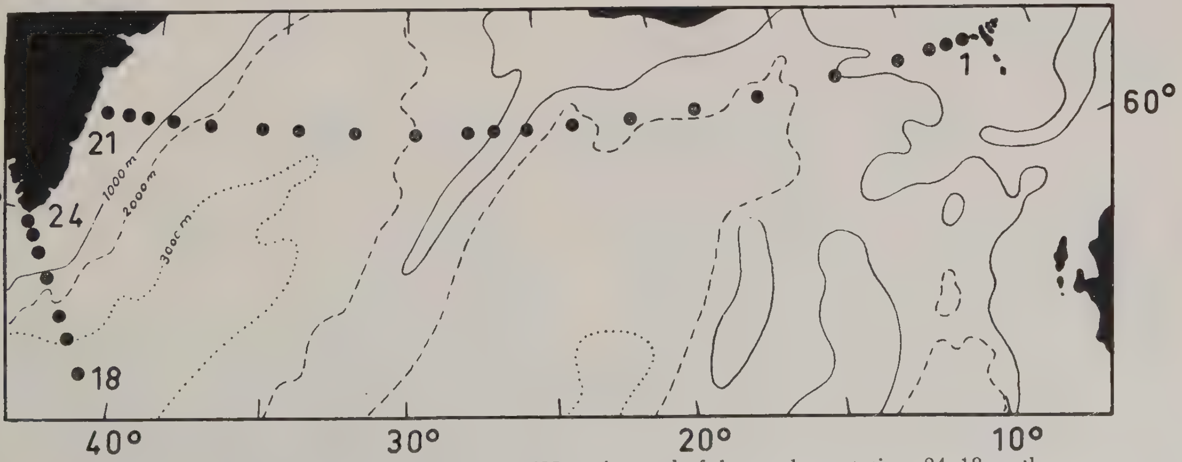


Figure 1. Positions of stations 1–21 at the 62°N section and of the northern stations 24–18 on the Cape Farewell/Ireland section.

Occurrence of *Sebastes* Fry on the Four Sections (and Areas)

1. Faroe-Shetland Channel (Table 1)

This section was studied yearly in June between 1946 and 1957. With the exception of 1952 and 1953, the catches were poor. There appears to be no agreement between the yearly catches from this section and those from the others. But, of course, several conditions, such as differences in the time of the year, number of night and day hauls, etc. make comparisons difficult.

The size range may correspond to the group of small larvae taken in the eastern part of the 62° section (from approximately the Faroes to the Reykjanes Ridge) allowing for the difference of time (1–2 mm smaller). A few of the larvae were of the same size as at extrusion (Ehrenbaum, 1936; Templeman, 1959).

The size range of the small collection of *Sebastes marinus* fry taken in June from the coastal waters of the Faroes is identical to that of the larvae taken between the Shetlands and the Faroes.

In four of the years, the Faroe-Shetland section was studied again later in the summer (July-August). By then the *Sebastes* larvae had almost disappeared. The same was true in November and December, 1951.

2. The 62° section from the Faroes to East Greenland (Tables 2–5)

A brief scrutiny of the length and frequency distribution of the *Sebastes* fry indicated quite interesting features, and some calculations were therefore tried on this material, which indicated that it was reasonable to stick mainly to the stations west of the Reykjanes Ridge.

If it is assumed that the hauls taken from the Irminger Sea each year are a random sample and that the numbers of *Sebastes* per haul are log. normally distributed, the Bartlett test indicates that it is very reasonable to assume that the variance is constant from year to year. The material was therefore arranged for an analysis of variance. Table 3 gives the figures of this analysis, showing a real difference in the yearly means.

The material is split up into day and night hauls. The night figures indicate that the day and night variance are equal, whereas the mean night catch is about 5·1 times the mean day catch.

In Table 4 the length distributions of the larvae are given for the years 1950 and 1957. An examination of these figures shows that a possible explanation of the

Table 1

Number and length of fry of *Sebastes marinus* in the Faroe-Shetland Channel 1946—1957

Year	Date	Numbers	Length (mm)												Cruises at other periods	Numbers
			5	6	7	8	9	10	11	12	13	15	22	30		
1946	26.–27. Aug.	0														
1947	10. June	3	–	–	1	1	–	1	–	–	–	–	–	–	19. July	0
1948	19.–20. June	6	–	–	–	–	1	2	–	2	1	–	–	–	12.–13. Aug.	1/22
1950	31. May–2. June	18	1	5	9	3	–	–	–	–	–	–	–	–	17.–18. Aug.	0
1951	8.–9. June	7	–	2	–	2	1	1	–	1	–	–	–	–	21. Nov.–13. Dec.	0
1952	31. May–2. June	116	8	28	27	29	10	10	2	1	1	–	–	–		
1953	31. May–13. June	137	–	3	14	17	46	31	20	2	1	–	–	1*		
1954	4.–5. June	3	2	–	–	–	–	–	–	–	–	1	–	–		
1955	4.–6. June	43	2	11	22	6	2	–	-	–	–	–	–	–		
1956	19.–20. June	2	1	–	–	–	–	1	–	–	–	–	–	–		
1957	3.–8. June	10	–	–	2	2	4	1	1	–	–	–	–	–		
Total number		345	14	49	75	60	64	47	23	6	3	1	–	1		

* Plus 2 defective specimens.

Table 2

Number of fry of *Sebastes (marinus)* on the 62° section 1947—1958

Year	Number of stations (No. 21 off East Greenland, No. 1 off the Faroes)[1]																					
	21	20	19	18	17	16	15	14	13	12	11		10	9	8	7	6	5	4	3	2	1
1947	7	116	120	–	–	–	–	13	–	421	40		–	–	124	–	1	–	20	–	0	0
48	0	89	16	14	120	22	–	38	24	304	682		212	102	144	79	12	15	9	0	4	3
50	19	106	87	136	69	419	618	477	164	1616	2041		342	1136	1681	84	88	267	–	39	–	3
51	–	–	–	–	–	–	–	–	–	–	–		1136	1681	108	199	17	11	11	58	–	1
52	–	–	–	–	58	32	–	–	367	–	270		805	–	65	231	–	–	72	7	2	0
53	–	–	–	60	273	326	46	40	30	58	896		244	–	326	35	1	3	93	0	0	0
54	–	2	4	267	35	91	72	56	76	–	–		–	–	–	2	3	1	–	–	–	1
55	54	47	–	17	–	–	169	245	–	397	221		80	0	21	0	0	0	0	0	0	0
56	32	45	–	190	161	310	40	87	–	152	49	254[2]	15	3	3	–	0	0	2	0	4	0
57	–	15	–	40	68	150	312	48	65	9	36		77	20	16	3	1	0	0	35	1	0
58	2	46	–	8	23	170	24	12	58	53	86		172	16	0	1	0	1	0	0	–	–

1) Positions of stations 1–21, see Fig. 1.
2) High-speed tow net.

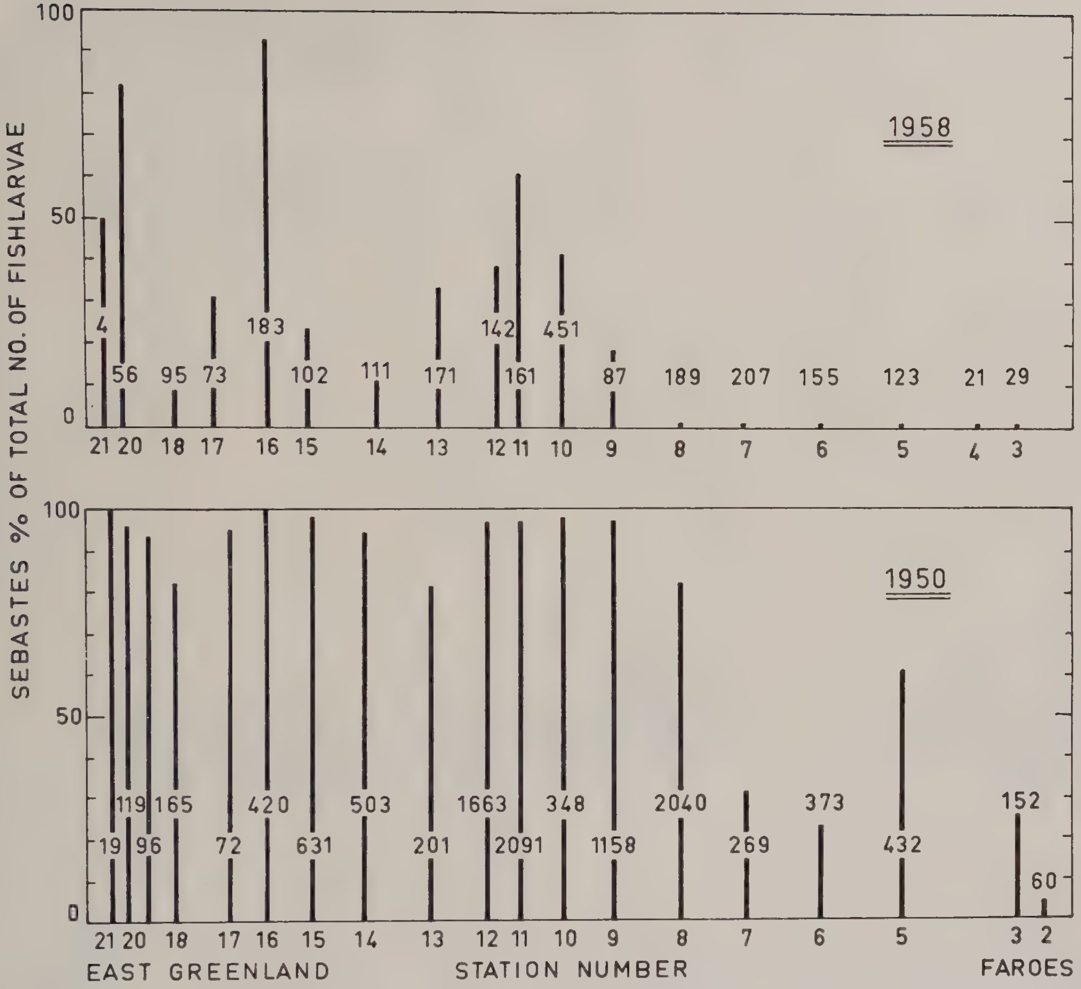


Figure 2. Percentage of *Sebastes* fry of the total number of fish larvae at the 62°N section (St. Nos. 2-21) in 1950 and 1958. The numbers in the columns indicate the total number of fish larvae.

irregularities is that three different groups of larvae are present. For 1950 and 1957 the three groups were:–

		1950			1957
a	mean	10·6 mm	a	mean	11·2 mm
	variance ...	2·3 mm^2		variance ...	2·3 mm^2
b	mean	13·0 mm	b	mean	14 0 mm
	variance ...	2·0 mm^2		variance ...	2·0 mm^2
c	mean	16·6 mm	c	mean	18·7 mm
	variance ...	5·6 mm^2		variance ...	3·5 mm^2

It is also worth drawing attention to the influence of the Reykjanes Ridge on the length of the larvae in some years. It should be mentioned that this influence is not found every year. In 1950 a very pronounced effect was found, whereas the material from 1957 did not show any effect whatever (Table 5).

The annual fluctuations suggest that young redfish were extremely abundant in 1950, whereas 1958 was a very poor year. But the conditions in 1950 were also exceptional in other respects (Fig. 2), *Sebastes* being the only predominant component of the fish larvae, of which only 1240 other specimens were caught (12 % of the total material). It may be mentioned that the 1950 year-class proved very important in the Greenland cod populations and the herring in Icelandic and Norwegian waters.

In 1958 the total number of other species amounted to 1,972 specimens, which corresponded to 75 % of the total material. The predominant species were *Myctophum glaciale* and *M. arcticum.*

In 1957 an exceptional inflow of Atlantic plankton took place. Figure 3 shows the conditions in the last part of June 1957. The quantity and the distribution of four important zooplankton elements are shown in

Table 3
Analysis of variance of the total catches of *Sebastes* larvae from the 62°N section

Day hauls

Year	Hauls n	Sum S	Sum of squares SS	$\frac{S^2}{n}$	Sum of sq. div. SSD	Degree of freedom f	Variance s^2	95 % confidence interval for mean catch
1947	5	8·13	15·07	13·23	1·84	4	0·46	29–216
1948	7	10·68	17·09	16·30	0·79	6	0·13	27–147
1950	7	16·15	38·14	37·24	0·90	6	0·15	162–887
1952	3	5·70	11·29	10·83	0·46	2	0·23	41–544
1953	7	13·23	26·04	25·02	1·02	6	0·17	62–340
1954	7	9·89	16·72	13·98	2·74	6	0·46	21–113
1955	6	11·60	23·48	22·41	1·07	5	0·21	64–401
1956	8	15·37	30·45	29·52	0·93	7	0·13	71–345
1957	9	15·29	27·71	25·96	1·75	8	0·22	44–198
1958	8	10·45	15·66	13·64	2·01	7	0·29	17–84

$v^2 = 2{\cdot}64\ (p \approx 1\ \%)$

$s_1^2 = 0{\cdot}24$ $s_2^2 = 0{\cdot}62$

Night hauls

Year	Hauls n	Sum S	Sum of squares SS	$\frac{S^2}{n}$	Sum of sq. div. SSD	Degree of freedom f	Variance s^2
1947	1	2·08	–	–	–	–	–
1948	2	5·32	14·19	14·13	0·06	1	0·06
1950	3	8·65	25·80	24·95	0·85	2	0·42
1952	1	2·56	–	–	–	–	–
1953	1	2·95	–	–	–	–	–
1954	1	2·43	–	–	–	–	–
1955	1	2·50	–	–	–	–	–
1956	1	2·18	–	–	–	–	–
1957	2	3·89	7·74	7·58	0·16	1	0·16

$s_1^2 = 0{\cdot}27$ $s_2^2 = 0{\cdot}20$

the upper part, the catches of *Sebastes* larvae are shown in the row of figures immediately beneath, and the simultaneous temperature conditions in the upper 100 metres, together with the lower level of the 2 m ring-net hauls, are shown in the lower part.

Inside the 200 m curve of the Faroes a neritic plankton occurred, dominated by Scyphomedusae, but larvae of Decapoda were also abundant.

Table 5
Mean length (mm) of *Sebastes* larvae at the different stations (see Fig. 1)

Station No.	Mean length 1950	Mean length 1957
1	9·0	–
2	–	–
3	–	–
4	11·1	9·3
5	–	–
6	11·6	–
7	11·8	–
8	10·9	–
9	10·8	14·5
10	10·7	12·1
11	10·0	13·0
Reykjanes Ridge		
12	14·0	13·6
13	15·1	14·0
14	13·2	13·6
15	13·8	14·5
16	15·3	12·7
17	13·3	13·2
18	13·4	14·5
19	14·2	–
20	12·9	11·0
21	14·1	–

In the core of Atlantic water *Salpa fusiformis* and Doliolidae were absolutely predominant, but if they are carried into water of lower temperature, such as is found west of the Reykjanes Ridge, they die. (Later in the summer *Salpa fusiformis* were so abundant in the Faxa Bay that they sometimes prevented commercial fishing.)

In the oceanic water *Aglantha* and a few species of Leptomedusae (*Halopsis ocellata* and *Laodicea undulata*) always make up a considerable part of the macroplankton. The conditions in 1957 did not favour the 1957 year-class of redfish, judging by this material. (The total number of other fish larvae was 373, which corresponded to 29 % of the total catch of fish larvae.)

Table 4
Length distribution of *Sebastes* larvae

mm	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Total number
1950																				
a	12	34	78	280	475	580	310	80	40	10	–	–	–	–	–	–	–	–	–	1,899
b	–	–	–	10	32	65	186	299	222	65	35	10	–	–	–	–	–	–	–	924
c	–	–	–	–	–	–	–	50	150	178	190	148	92	87	34	18	10	6	3	966
Total	12	34	78	290	507	645	496	429	412	253	225	158	92	87	34	18	10	6	3	3,789
1957																				
a	–	2	10	29	55	70	65	33	12	3	–	–	–	–	–	–	–	–	–	279
b	–	–	–	–	–	5	21	35	47	35	24	5	–	–	–	–	–	–	–	172
c	–	–	–	–	–	–	–	–	–	4	7	14	25	21	9	6	3	5	–	94
Total	–	2	10	29	55	75	86	68	59	42	31	19	25	21	9	6	3	5	–	545

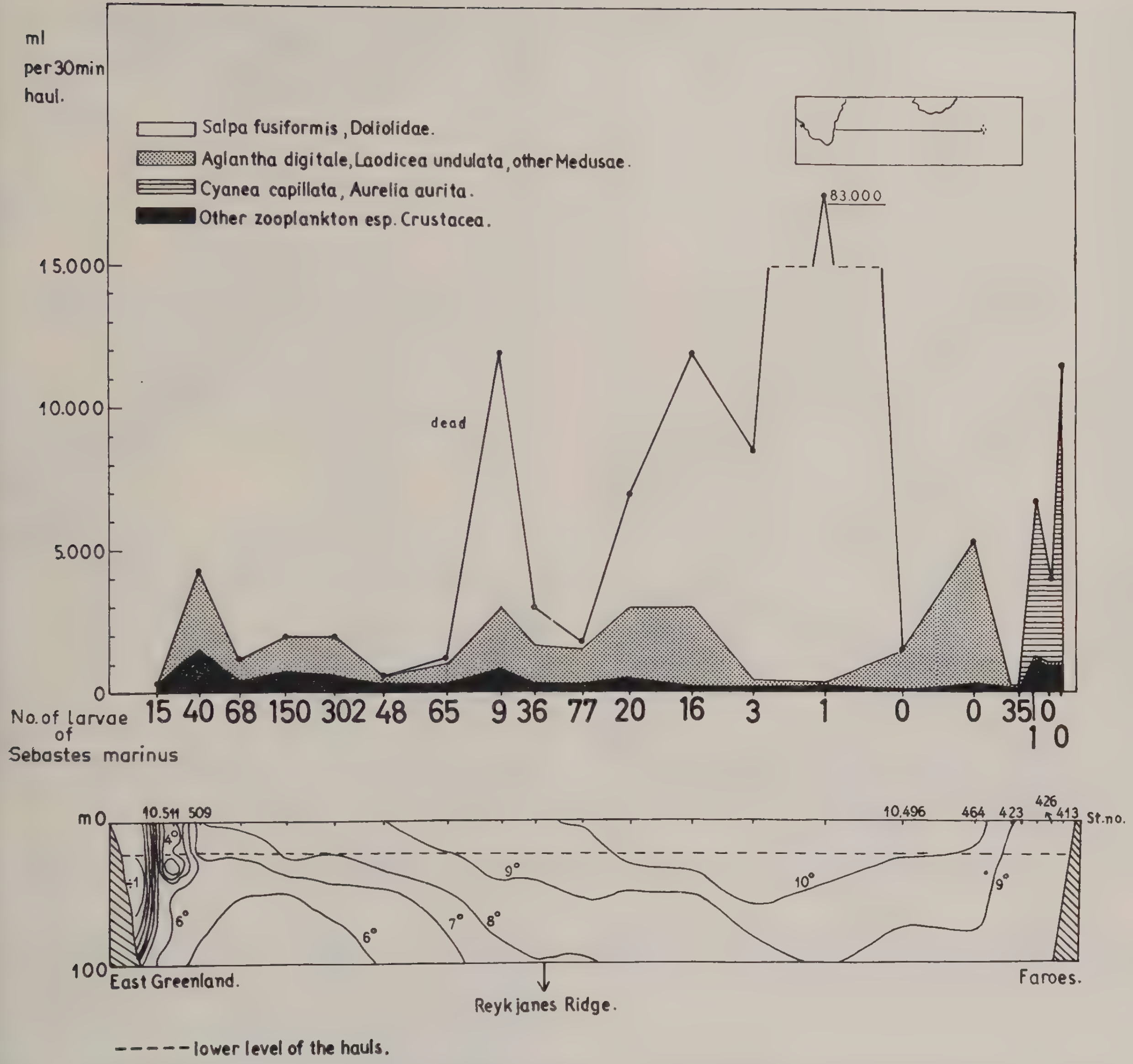


Figure 3. Quantity and composition of macroplankton, number of *Sebastes marinus* fry, and temperature in the upper 100 m at the 62°N section, 13. June–3. July 1957.

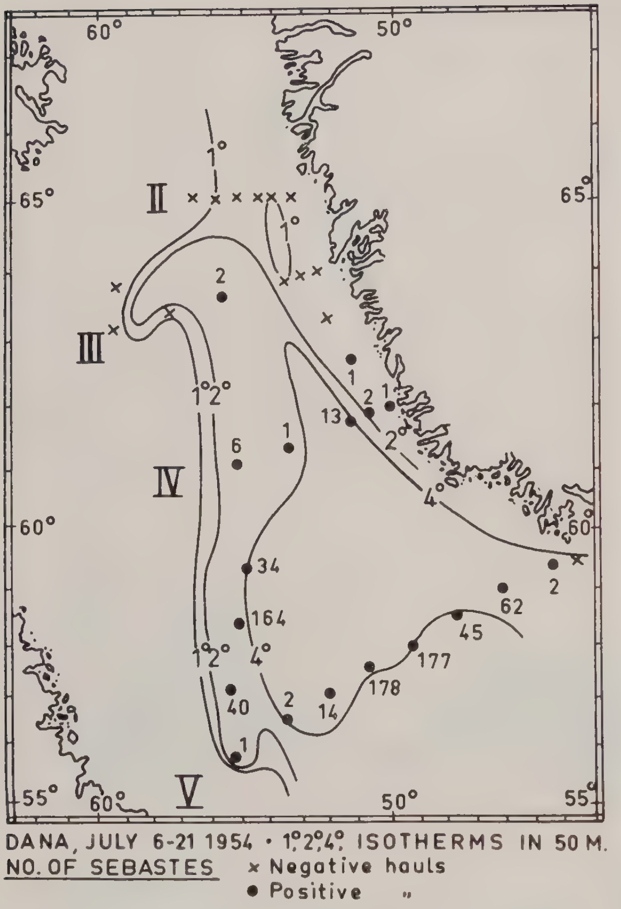
The influence of the Reykjanes Ridge (near station No. 12, Fig. 2) on the occurrence of the redfish larvae is evident.

3. The West Greenland waters (Tables 6–8)

In 1950 and every year since 1952, the "Dana" has made sections in July in West Greenland waters. *Sebastes* larvae have been found only on the sections south of the Holsteinsborg section, Section I (Fig. 5).

As seen in Figures 4 and 5 the *Sebastes* fry is restricted in its distribution to the water masses of Atlantic origin. Consequently, in some years only a very few are transported north of the Frederikshåb section, or, in other years, north of the Fylla Bank section. The distribution in July 1950 is given by Tåning (1951).

The total material from the West Greenland waters is tabulated in Table 6. As the length of the sections differed from year to year, especially in the southern region, the variations in the total yearly catches cannot be compared. The stations between Cape Farewell and 65°N (Section II) were well scattered in 1950 and only taken in the eastern part of the area. Only in 1953–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6
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164
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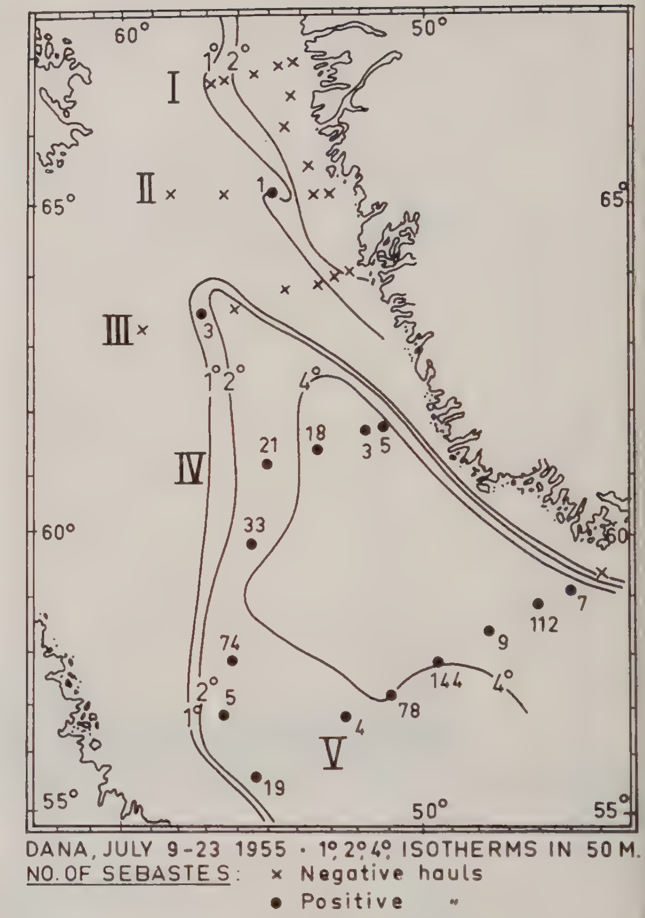
14
1
178
177
45
62
2
DANA, JULY 6-21 1954 · 1°2°4° ISOTHERMS IN 50 M.
NO. OF SEBASTES
× Negative hauls
● Positive "

Figure 4. The quantitative distribution of fry of *S. marinus* in West Greenland waters, July 1954.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144
9
112
7
DANA, JULY 9-23 1955 · 1°2°4° ISOTHERMS IN 50 M.
NO. OF SEBASTES:
× Negative hauls
● Positive "

Figure 5. The quantitative distribution of fry of *S. marinus* in West Greenland waters, July 1955.

Table 6

Number of fry *Sebastes* (*marinus*) on the standard sections (I-IV) in the Davis Strait, 1950—1959, and on Section V[1])

		Sections							
		I	II	III	IV		V		
Year	Date July	Holsteinsborg	Sukkertoppen	Fylla Bank	Frederikshåb	Total	Cape Farewell/ Hamilton Inlet	Between Section IV and V	Total
1950	2–6	0	0	6	24	30	701		731
1952	6–12	0	0	7	105	112	102	41	255
1953[2])	2–16	0	0	1	122	123	183	291	597
1954[2])	6–21	0	0	2	24	26	481	138	645
1955[2])	9–23	0	1	3	47	51	373	112	536
1956	10–18	0	0	10	253	263	2	–	265
1957	7–18	0	18	185	248	451	14	–	465
1958	12–23	2	3	33	23	61	2	–	63
1959	10–20	0	0	8	6	14	92	29	135

[1]) Positions of Sections I–V, see Fig. 5.
[2]) The whole Section V was made only in 1953–55.

1955 was the full length of the Cape Farewell/Hamilton Inlet section (Section V) worked (7–9 stations). In these years by far the greatest number of *Sebastes* was caught in the southern region. A considerable part of Section V was worked in 1958 (6 stations) but in the rest of the years (1950, 1952, 1956, 1957, 1959) only a few stations were occupied; consequently only a small portion of *Sebastes* was taken in this area.

In the region of Section IV (Frederikshåb section) and northwards, the positions and length of the sections are practically constant and the yearly variations are dependent on the inflow of water of Atlantic origin. The collections suggest that *Sebastes* were extremely abundant in 1957. There was also a correspondingly successful year-class of cod in that year.

The size range of the populations taken on the different sections usually indicates a decrease of length, going northwards, (Table 7). The size distribution in the whole area indicates that the greatest part of the

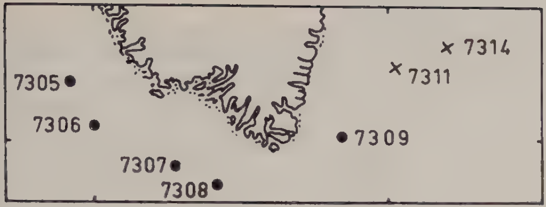

Figure 6. Positions of St. 7305–7314, 22.–25. July 1950 (see text).

Table 7
Mean length of fry of *Sebastes marinus* in West Greenland waters in 1954 and 1955

Section (Positions, see Fig. 5)	Mean length, mm 1954	 1955
II and III	–	9·5
IV	11·0	10·4
Between IV and V	12·5	11·9
V	11·9	11·6

population belongs to the group of low mean length mentioned, group *a* (Fig. 8).

Of particular interest is the material collected in the period 22.–25. July 1950 (Table 8, Fig. 6). The *Sebastes* from St. 7305–7309 were of the same size range (the individual of 26 mm length was caught at St. 7309, where five other large specimens were taken, neasuring 9, 12, 13, 15, and 16 mm respectively) whilst he size distribution of the material from St. 7311 and St. 7314 was quite different, indicating quite another population.

. The section Cape Farewell/Ireland (Table 9)

In 1952 and every year since 1954, the "Dana" has vorked a section from Greenland to Ireland in ıbout the middle of August (see Fig. 1). During these ruises *Sebastes* larvae were found at only 10 stations 19 hauls), all of which were situated north of 7°30′N, 40°00′W. Every year series of deep hauls, vith a max. 1400 m of wire, have been taken at about he position given above. Only in three deep hauls were *ebastes* larvae caught and then only one specimen ber haul.

With the exception of the hauls at St. 10.053, 3. ugust 1956 (see Table 12), where 62 specimens were aken in the upper standard haul and 104 specimens in he lower one, the catches of *Sebastes* larvae in this rea have been remarkably poor and the populations vere restricted to the surface layers. The size range aried very much, from 10 mm to 40 mm.

Table 8
Number and length of two populations of fry of *Sebastes* (*marinus*) in the Cape Farewell area in July 1950
(Positions of Stations, see Fig. 6)

St. Nos.	Date July	Total no.	Length (mm) 9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
7305–09	22.–24.	82	2	4	8	12	15	14	11	6	6	2	–	1	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
7311 7414	25.	118	–	–	–	–	1	1	1	1	5	3	3	3	4	3	6	10	5	8	2	3	5	1	6	6	3	3	8	7	9	3	1	6	1

Table 9
Number and length of fry of *Sebastes marinus* on the section Cape Farewell–Ireland
(*Sebastes* larvae are found only on the part of the section shown in Fig. 1.)

Year	Date August	No. of positive hauls	No. of larvae	Length (mm) 10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
1952	14.–15.	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1954	22.–23.	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1955	13.–14.	3	9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	2	–	–	–	–	–	1	1	1	–	–	–	2	–	–	–
1956	1.–3.	7	192	1	–	–	–	10	7	6	8	12	16	25	19	11	11	25	14	13	3	3	2	–	2	1	2	1	–	–	–	–	–	–	–	–	–
1957	8.–11.	9	38*	–	1	4	–	1	5	3	1	1	2	–	–	–	–	–	–	2	1	2	1	–	1	1	1	–	1	–	3	2	2	–	1	–	1
1958	15.–17.	0	0																																		

* 1 specimen defective

Remarks on the Oceanic Distribution

In June-July 1947, a cruise was made in the North Atlantic between 50°N and 62°N and westwards to about 45°W. Tåning (1949) has discussed the outlines of the *Sebastes* problem in the ocean, based mainly upon the material from this cruise. His conclusions were, as is well known, that the postlarvae in the area described in this paper, are abundant only above areas where the temperatures of the water in depths of 200 to 500 m are between 3–4°C and 8–8·5°C.

Figure 7 shows the catches of *Sebastes* fry in the standard hauls (number per hour) at all the stations worked up. The importance of the bottom configuration is evident, since the greatest catches which were taken in the slope areas of the Irminger Sea (28.–29. June) may have accumulated by transportation from the surrounding areas. As this material is so important for the understanding of Tåning's theory, we have listed the total material in detail in Table 10. Concerning the material from 1947 of fry of *Sebastes viviparus* and other *Sebastes* fry with ventral caudal melanophores vide pp. 214–15.

In Figure 8 is shown the occurrence of the three size groups, mentioned previously, in the 1947 material. As comparable material does not exist for the West Greenland waters for all the years since 1947, the conditions for 1954, 6.–21. July, are demonstrated. The three size groups suggest repeated "spawnings". The distribution of the size groups indicates that all three groups occur in the areas in which *S. marinus* fry is found in abundance. In the slope areas the "spawning *in situ*" may cause an accumulation of fry from different "spawnings"; in the intervening oceanic regions (such as the Irminger Sea) the large populations found may originate from the surrounding slope areas. But outside these areas the transport possibilities are slight and the populations consist of only one size group (sometimes two).

In the West Greenland waters size group *a* has been the only important group in the years investigated (1950, 1952–1959); only at 1–3 stations per year were more than one size group found.

The vertical distribution (Tables 10–12)

In the area in which the maximum abundance of *Sebastes* fry has been found, i.e., on the 62° section from a little east of the Reykjanes Ridge and westwards, a shallow scattering layer is usually registered at 5–30 m depth (echo-sounder: Bendix DR-12).

Figure 9 shows the conditions on 4. July 1956, at 61°56′N, 26°01′W. The scattering layer was recorded

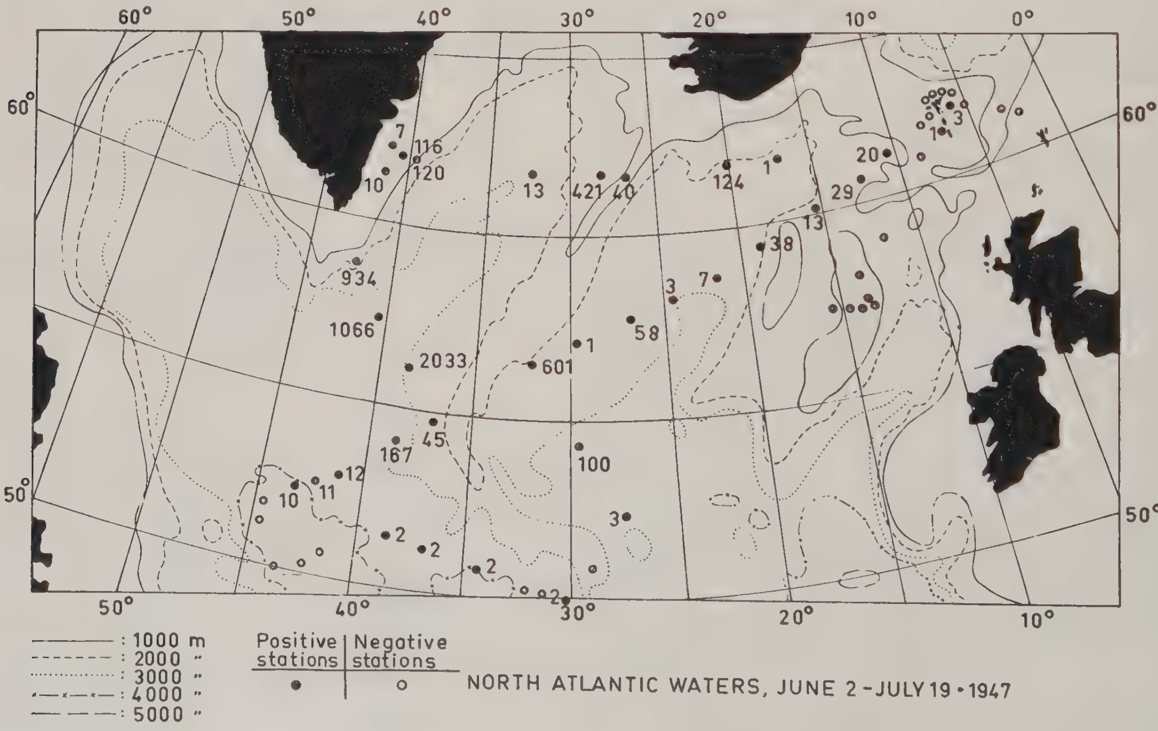

Figure 7. The quantitative distribution of fry of *Sebastes marinus*, June and July, 1947. Number per one hour's catch with standard hauls I and II. (After Dietrich, 1957).

Table 10

Number and length (mm) of fry of *Sebastes* (*marinus*) in the North Atlantic taken in 2 m stramin net in the period 3. June—15. July 1947

. No.	Date	Position N W	m wire	Duration min.	Total no.	Length (mm) 7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
16	June 3	57°27′–13°36′	150–100–50	3×10	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
17	3	57°15′–13°14′	"	"	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
18	3	57°11′–12°37′	"	"	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
19	3	57°18′–14°00′	"	"	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
20	4	57°22′–14°45′	"	"	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
21	4	57°26′–15°24′	"	"	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
23	5	58°07′–13°41′	"	"	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
27	5	58°59′–12°07′	"	"	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
43	7	60°55′– 8°42′	"	"	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
48	7	61°33′– 7°14′	"	"	1	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
51	10	62°05′– 6°10′	"	"	3	1	1	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
53	10	62°25′– 6°12′	100– 50– 25	"	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
54	10	62°30′– 5°55′	"	"	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
55	10	62°28′– 6°43′	150–100– 50	"	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
59	14	61°40′– 8°17′	600	60	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		"	300	"	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		"	200	"	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	15	"	100– 50– 25	3×10	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
60	15	61°15′–10°19′	"	"	18	1	6	5	4	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		"	200–150–125	"	2	–	–	1	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
61	15	60°47′–12°33′	600	60	8	–	1	–	1	2	3	–	1	–	–	–	–	–	–	–	–	–	–	–
		"	300	"	5	–	1	1	2	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–
		"	200	"	8	–	1	1	–	3	3	–	–	–	–	–	–	–	–	–	–	–	–	–
		"	200–150–125	3×10	4	–	–	–	1	1	–	2	–	–	–	–	–	–	–	–	–	–	–	–
		"	100– 50– 25	"	25	–	–	–	–	2	3	9	8	1	1	–	–	1	–	–	–	–	–	–
62	16	60°09′–15°30′	200–150–125	"	3	–	–	1	–	1	–	–	1	–	–	–	–	–	–	–	–	–	–	–
		"	100– 50– 25	"	10	–	1	–	1	7	1	–	–	–	–	–	–	–	–	–	–	–	–	–
63	16	59°29′–18°34′	200–150–125	"	6	–	–	–	–	3	2	1	–	–	–	–	–	–	–	–	–	–	–	–
		"	100– 50– 25	"	32	–	–	–	3	14	10	3	2	–	–	–	–	–	–	–	–	–	–	–
64	17	58°50′–21°34′	200–150–125	"	4	–	1	1	–	1	1	–	–	–	–	–	–	–	–	–	–	–	–	–
		"	100– 50– 25	"	3	–	–	–	–	1	–	2	–	–	–	–	–	–	–	–	–	–	–	–
65	17	58°24′–24°31′	200–150–125	"	1	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		"	100– 50– 25	"	2	–	–	1	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
66	17	57°39′–26°58′	600	60	13	–	–	1	2	2	1	2	2	2	–	1	–	–	–	–	–	–	–	–
		"	300	"	7	–	–	3	–	1	–	2	1	–	–	–	–	–	–	–	–	–	–	–
		"	200	"	7	2	–	3	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–
	18	"	200–150–125	3×10	13	–	–	1	3	–	2	2	1	2	–	–	–	1	1	–	–	–	–	–
		"	100– 50– 25	"	45	–	–	–	–	4	8	7	8	5	4	5	2	1	–	–	–	–	–	1
67	18	57°02′–29°31′	200–150–125	"	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		"	100– 50– 25	"	1	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–
68	18	56°30′–32°00′	600	60	9	–	–	–	–	4	4	–	–	–	1	–	–	–	–	–	–	–	–	–
		"	300	"	13	–	–	–	4	–	3	3	2	1	–	–	–	–	–	–	–	–	–	–
		"	200	"	15	–	–	–	1	–	3	2	4	–	–	–	1	–	–	3	1	–	–	–
		"	200–150–125	3×10	161[2])	–	1	5	19	30	48	20	12	6	7	2	6	2	2	–	–	–	–	–
		"	100– 50– 25	"	440[1])	–	3	6	21	34	48	46	23	8	4	4	2	1	–	–	–	–	–	–
1	19	54°29′–29°42′	600	60	10	–	–	–	–	–	3	–	–	1	–	–	6	–	–	–	–	–	–	–
		"	300	"	13	–	–	1	–	–	1	1	–	4	3	2	1	–	–	–	–	–	–	–
		"	200	"	6	–	–	–	–	–	–	–	1	–	–	1	1	–	2	1	–	–	–	–
		"	200–150–125	3×10	43	–	–	–	1	–	1	–	1	2	5	5	13	8	5	2	–	–	–	–
		"	100– 50– 25	"	57	–	–	–	–	1	3	1	7	6	14	6	10	5	4	–	–	–	–	–
4	20	52°20′–27°30′	2000	120	2	–	–	–	–	–	–	–	–	1	–	1	–	–	–	–	–	–	–	–
		"	1000	"	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		"	600	60	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		"	300	"	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		"	200	"	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		"	200–150–125	3×10	2	–	–	–	–	–	–	–	–	1	–	–	1	–	–	–	–	–	–	–
		"	100– 50– 25	"	1	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–
6	21	51°07′–28°54′	100	30	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		"	0	"	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
8	22	49°48′–30°25′	50	"	1	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–

(continued on next page)

00 specimens measured.

+ 1 specimen defective.

Table 10 (continued)

St. No.	Date	Position N W	m wire	Duration min.	Total no.	Length (mm)																		
						7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
79	June 22	48°57′–31°15′	200	„	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		„	100	„	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
81	23	50°09′–32°19′	200	„	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		„	100	„	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		„	25	„	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
83	24	50°53′–34°25′	600	60	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		„	300	„	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		„	200	„	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		„	200–150–125	3×10	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		„	100– 50– 25	„	1	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–
85	24	51°07′–36°58′	200–150–125	„	2	–	–	–	–	–	–	1	1	–	–	–	–	–	–	–	–	–	–	–
		„	100– 50– 25	„	1	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–
86	25	51°16′–38°33′	200–150	2×15	14	–	–	–	–	1	3	4	6	–	–	–	–	–	–	–	–	–	–	–
		„	100– 50	„	39	–	–	–	–	1	2	4	13	15	2	2	–	–	–	–	–	–	–	–
88	26	50°34′–41°39′	200–150	„	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		„	100– 50	„	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
89	26	50°14′–42°24′	200–150–125	3×10	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		„	100– 50– 25	„	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
90	26	50°00′–43°29′	200–150–125	„	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		„	100– 50– 25	„	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
91	27	51°00′–44°20′	600	60	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		„	300	„	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		„	200	„	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		„	200–150–125	3×10	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		„	100– 50– 25	„	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
92	27	51°30′–44°20′	200–150–125	„	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		„	100– 50– 25	„	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
93	27	52°06′–43°04′	200–150–125	„	3	–	–	–	–	1	1	–	1	–	–	–	–	–	–	–	–	–	–	–
		„	100– 50– 25	„	7	–	–	–	1	–	2	4	–	–	–	–	–	–	–	–	–	–	–	–
94	27	52°24′–42°24′	200–150–125	„	3	–	–	–	–	1	1	–	1	–	–	–	–	–	–	–	–	–	–	–
		„	100– 50– 25	„	8	–	–	–	2	1	3	1	–	1	–	–	–	–	–	–	–	–	–	–
95	28	52°48′–41°29′	200–150–125	„	10	–	–	1	1	2	–	1	3	–	2	–	–	–	–	–	–	–	–	–
		„	100– 50– 25	„	2	–	–	–	–	–	–	–	1	1	–	–	–	–	–	–	–	–	–	–
97	28	54°02′–38°35′	100	30	167	–	–	7	14	43	54	25	13	9	1	1	–	–	–	–	–	–	–	–
98	29	54°40′–37°00′	200–150	2×15	10	–	–	1	1	5	1	–	1	–	1	–	–	–	–	–	–	–	–	–
		„	100– 50	„	35	–	–	3	11	7	3	5	2	3	–	–	1	–	–	–	–	–	–	–
99	29	56°02′–38°43′	2000	120	95	–	1	–	2	6	11	15	25	18	10	5	1	1	–	–	–	–	–	–
		„	1500	„	75	–	1	2	2	8	12	13	15	10	6	3	–	2	1	–	–	–	–	–
		„	600	60	19[2])	–	–	–	–	–	3	9	2	1	1	2	–	–	–	–	–	–	–	–
		„	300	„	24	–	–	1	–	2	6	6	3	2	3	1	–	–	–	–	–	–	–	–
		„	200	„	59	–	–	–	–	5	9	16	15	6	4	2	–	–	–	1	1	–	–	–
		„	200–150–125	3×10	1072[1])	–	–	2	1	5	24	41	55	34	21	7	3	3	3	1	–	–	–	–
		„	100– 50– 25	„	961[1])	–	2	4	14	29	40	39	37	15	7	6	3	2	1	–	1	–	–	–
6700	30	57°22′–40°28′	200–150–125	„	365[1])	–	1	18	41	58	52	21	5	–	4	–	–	–	–	–	–	–	–	–
		„	100– 50– 25	„	701[1])	–	1	9	35	64	50	29	9	1	1	–	1	–	–	–	–	–	–	–
01	June 30	58°32′–42°06′	200–150–125	„	202	–	–	13	30	55	51	24	10	10	7	1	1	–	–	–	–	–	–	–
		„	100– 50– 25	„	732[1])	–	–	13	36	39	47	28	18	9	5	4	1	–	–	–	–	–	–	–
02	July 1	61°00′–39°55′	100	30	606[1])	–	–	1	3	21	60	62	34	13	4	1	1	–	–	–	–	–	–	–
03	2	61°19′–41°30′	200–150–125	3×10	4	–	–	2	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		„	100– 50– 25	„	6	–	1	2	2	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
04	2	62°00′–41°07′	200–150–125	„	3	–	–	1	1	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–
		„	100– 50– 25	„	4	–	1	1	1	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–
05	2	61°55′–40°47′	200–150–125	„	15	–	1	4	6	2	1	1	–	–	–	–	–	–	–	–	–	–	–	–
		„	100– 50– 25	„	101	2	19	32	25	14	4	–	2	–	–	1	–	2	–	–	–	–	–	–
06	2	61°55′–39°55′	200–150–125	„	44	–	–	5	13	14	1	9	–	1	–	–	1	–	–	–	–	–	–	–
		„	100– 50– 25	„	76	2	–	6	23	22	11	4	–	2	1	1	–	4	–	–	–	–	–	–
07	3	61°47′–32°38′	200–150–125	„	3	–	–	–	–	1	1	–	1	–	–	–	–	–	–	–	–	–	–	–
		„	100– 50– 25	„	10	–	–	–	–	–	2	2	2	1	–	–	–	–	1	1	–	1	–	–
08	4	61°50′–28°10′	200–150–125	„	125	–	–	1	2	6	9	10	12	24	20	21	11	7	1	–	1	–	–	–
		„	100– 50– 25	„	296[1])	–	–	2	13	17	21	31	28	22	30	21	13	1	1	–	–	–	–	–
09	4	61°42′–26°52′	200–150–125	„	11	–	–	–	–	–	1	1	1	4	3	–	1	–	–	–	–	–	–	–
		„	100– 50– 25	„	29	–	–	1	2	2	3	4	6	3	6	1	–	1	–	–	–	–	–	–
11	5	61°51′–20°20′	200–150	2×15	101	–	–	3	2	1	7	6	23	21	25	10	2	1	–	–	–	–	–	–
		„	100– 50	„	23	–	–	–	–	2	2	3	3	10	3	–	–	–	–	–	–	–	–	–

[1]) 200 specimens measured.
[2]) + 1 specimen defective.

Table 10 (continued)

o.	Date	Position N W	m wire	Duration min.	Total no.	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
						Length (mm)																		
	5	61°57'–17°23'	200–150–125	3×10	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		”	100– 50– 25	”	1	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–
	14	61°50'– 7°25'	200–150–125	”	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		”	100– 50– 25	”	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	July 15	62°20'– 7°10'	100– 50	2×15	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

St. 6704 to 6717 belong to the 62° section, see Table 2.

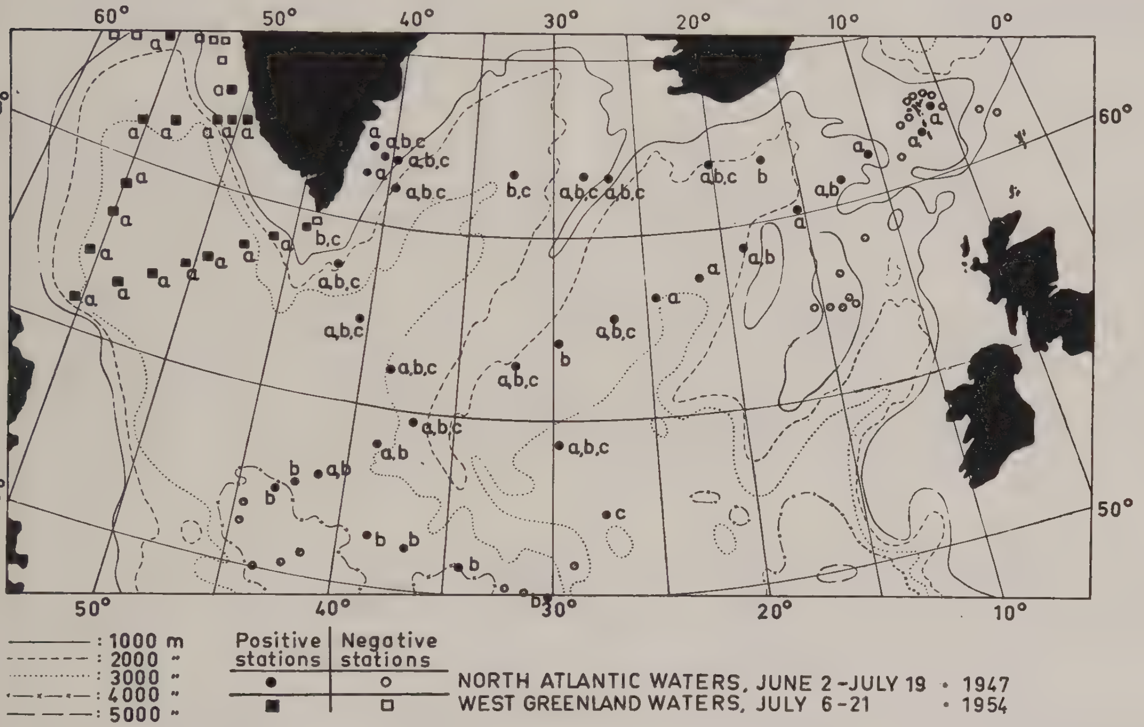
60°
50°
40°
30°
20°
10°
0°
60°
50°
a
b
c
a,b,c
: 1000 m
: 2000 "
: 3000 "
: 4000 "
: 5000 "
Positive stations
Negative stations
NORTH ATLANTIC WATERS, JUNE 2 -JULY 19 · 1947
WEST GREENLAND WATERS, JULY 6-21 · 1954

Figure 8. The distribution of size groups a, b, and c, June–July 1947 (North Atlantic) and July 1954 (in the Davis Strait and West Greenland waters). (After Dietrich, 1957).

Table 11

Number of *Sebastes marinus* fry in vertical series of hauls

Year Date	1947, '48, '50, '52 15. June–1. July		1948 17. July	1956 2. Aug.	1957 10. Aug.	1955 13. Aug.	1958 17. Aug.	1954 22. Aug.
m wire	Number of hauls	Aver no. per haul/hr	Number of fry of *Sebastes marinus* per hour					
100–50–25	16	740	162	124	4	2	0	0
200–150–125	16	311	16	208	8	14	0	0
300	16	31	14	–	–	–	–	–
400	–	–	–	2	–	–	0	0
600	16	39	6	–	–	0	–	0
1000–600	7	45	31	0	2	0	0	0
2000–1000	2	43	–	–	1	–	–	–

Each catch refers to one haul

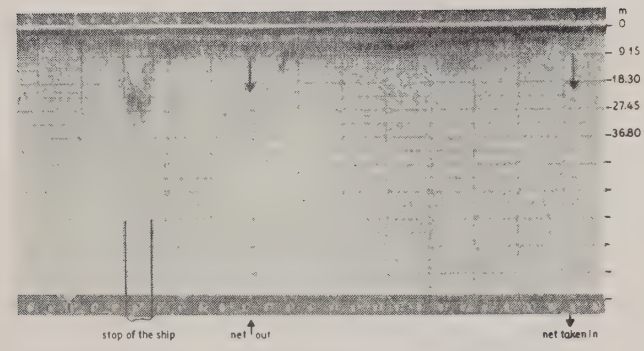

Figure 9. Echo-traces of *Sebastes* fry and other fish fry (see text).

over a distance of about 17 miles. A high-speed tow net (diameter 1 m) was towed 2 × 15 min. with 50 and 30 m wire respectively at a speed of 6 knots. A depressor (19 kg) was shackled to the end of the wire.

When the ship stopped the fish were frightened and some of them descended to a depth of 20–30 m, but were soon afterwards found at the upper level previously recorded.

The catch consisted of: 90 ml of invertebrates (*Aglantha* (x), *Calanus finmarchicus* (cc), other copepods (r), *Themisto* (x), and Euphausiacea furcilia (rr)). (Symbols: rr = very rare; r = rare; x = occasional; c = common; cc = very common.)

Of fish there were: 3 *Motella*; 3 *Gadus poutassou* (measuring 14, 15, and 18 mm respectively); 1 *Zeugopterus megastoma* (12 mm); 254 *Sebastes (marinus)* measuring (mm):– 1/6, 20/9, 22/10, 60/11, 70/12, 30/13, 17/14, 7/15, 1/16, 6/17, 5/18, 1/19, 6/20, 2/21, 1/22, 3/24, 1/25, and 1/26.

At the next station (No. 11, see Fig. 1 and Table 2) 49 *Sebastes* were caught in the two standard hauls with the 2 m ring-net. They were of approximately the same size, between 9 mm and 23 mm. This indicates that the 2 m ring-net sampled the whole size range of *Sebastes* fry in the area and at the time in question.

Table 12

Number and length of *Sebastes marinus* fry in vertical series of hauls

Station No.*	6699								6914	10.053	10.580	97
Date, Year	29. June 1957								17. July 1948	3. Aug. 1956	10. Aug. 1957	13. Aug
m wire	2000	1500	600	300	200	200–150–125	100–50–25	Total	Total no. of hauls. Max. m wire: 1400 m			
Duration, min.	120	120	60	60	60	30 **	30 **	480	150	120	180	12
Length, mm												
8	1	1	–	–	–	–	10	12	–	–	–	–
9	–	2	–	1	–	11	19	33	1	–	–	–
10	2	2	–	–	–	5	67	76	6	–	–	–
11	6	8	–	2	5	27	139	187	–	–	–	–
12	11	12	3	6	9	129	192	362	1	–	–	–
13	15	13	9	6	16	220	187	466	2	–	–	–
14	25	15	2	3	15	295	178	533	–	9	–	–
15	18	10	1	2	6	182	72	291	2	4	1	–
16	10	6	1	3	4	112	34	170	1	3	–	–
17	5	3	2	1	2	38	29	80	7	7	–	–
18	1	–	–	–	–	16	14	31	15	7	–	–
19	1	2	–	–	–	16	10	29	19	11	–	–
20	–	1	–	–	–	16	5	22	18	21	–	–
21	–	–	–	–	1	5	–	6	22	19	–	–
22	–	–	–	–	1	–	5	6	19	11	–	–
23	–	–	–	–	–	–	–	–	8	11	–	–
24	–	–	–	–	–	–	–	–	3	25	–	–
25	–	–	–	–	–	–	–	–	3	14	–	–
26	–	–	–	–	–	–	–	–	5	13	2	1
27	–	–	–	–	–	–	–	–	4	3	1	–
28	–	–	–	–	–	–	–	–	3	3	2	2
29	–	–	–	–	–	–	–	–	1	2	1	–
30	–	–	–	–	–	–	–	–	–	0	–	–
31	–	–	–	–	–	–	–	–	–	2	–	–
32	–	–	–	–	–	–	–	–	–	1	–	–
33	–	–	–	–	–	–	–	–	–	1	–	–
34	–	–	–	–	–	–	–	–	–	1	–	1
35	–	–	–	–	–	–	–	–	–	–	1	1
36	–	–	–	–	–	–	–	–	–	–	–	1
37	–	–	–	–	–	–	–	–	–	–	–	–
38	–	–	–	–	–	–	–	–	–	–	–	–
39	–	–	–	–	–	–	–	–	–	–	1	–
40	–	–	–	–	–	–	–	–	–	–	–	2

* Positions of stations: 6699, 56°02′N, 38°43′W; 6914, 61°57′N, 40°41′W; 10.053, 57°00′N, 39°29′W; 10.580, 58°00′N, 41°03′W; 9790, 58°00′N, 41°03′W.

** See also Table 10.

At three stations (in 1948 and 1950) series of hauls vith the 2 m ring-net were taken in the upper 45 m. The material confirms the echo-sounding survey:–

m wire	No. of *Sebastes*
15 and 25	38
100–50–25	1003
200–150–125	350

A considerable number of deep hauls were worked, vith 2000 m wire as the deepest hauls.

The material represented in Table 11 confirms the echo-sounding surveys that the bulk of fry of *S. marinus* s found in the upper 50 m in June–July.

As closing nets were not used the hauls may be characterized as horizontal-oblique hauls. Consequently the main part of catches taken during the deep hauls was probably made when the nets were hauled through the upper strata. The length distribution is almost dentical in the catches from the different depths (Table 12, St. 6699).

In Table 11 the catches from the second half of June are summarized, whereas the deep-haul stations from July and August are given separately.

In the middle of August the *Sebastes* fry disappear both in the upper and in the deep hauls (max. depth about 300 m). The *Sebastes* have then a length of 26–40 mm (Table 12), and are thus of a size at which t is still possible to catch them with the 2 m ring-net (see also Table 9). Consequently it may be concluded that in mid-August the fry of *Sebastes marinus* descends to a depth of 300–400 m in the oceanic area in question. At this time they have a length of about 30–40 mm.

Investigations from Weather Ship 'B' in the Davis Strait (Kielhorn, 1952) and from Weather Ship 'A' in the Irminger Sea (authors' investigations) have shown that the zooplankton disappears from the upper 100 m in August. According to the investigations from Weather Ship 'M' in the Norwegian Sea (Østvedt, 1955; Wiborg, 1954) the descent of the zooplankton takes place there in June-August. It hibernates in the deep water (600–2000 m). The ascent of the zooplankton to the surface layers takes place in April-May. The moulting from stage V to sexually mature stage, in the most important copepod species, occurs prior to or during the ascent (*Calanus hyperboreus* and *Pseudocalanus minutus*) or after the migration has been completed (*Calanus finmarchicus*) (Østvedt, 1955). Immediately after moulting, spawning occurs. Unfortunately no observations on the possible fluctuations in the outburst of the phytoplankton bloom and the spawning of the zooplankton are available from the whole area in question, but it is thought that the question of food available at the time of extrusion of the redfish larvae is the main cause of the yearly variations demonstrated in the North Atlantic.

Pelagic Catches of Adult and Adolescent Stages of *Sebastes marinus*

Specimens at these stages have been caught only in our cases during the "Dana" cruises in the North Atlantic.

1. At St. 4206, 1. July 1931, one male of 48 cm, at 300 m over a depth of 3,300 m (Tåning, 1949). Pelagic trawl. Position 53°38′N–29°41′W.
2. At St. 6899, 27. June 1948, one female of 49 cm, at 300 m over a depth of 800 m. Pelagic trawl. Position 62°00′N–26°30′W (62° section St. 11).
3. In 1953 the "Dana" stopped on the 62° section at about 32°W for repairs to the engine. One *Sebastes* 30–40 cm long was caught by a jig with 30–50 m line. Unfortunately no biologist was on bcard and no other information is available.
4. At St. 10.580, 11. August 1957. Position 58°00′N–41°03′W (SE of Cape Farewell), depth 3,080 m. Gear S.200. 4 hauls were made:–

	m wire	Lengths of *Sebastes*
(1)	1400–1200–1000	1/26 mm, 1/35 cm
(2)	800–600–400	1/39 cm
(3)	200–150–125	1/15, 1/26, 1/27, 1/28 mm ex.c.
(4)	100–50–25	1/28, 1/29 mm

The macroplankton in the upper strata in the last mentioned area is usually characterized by large individuals of the deep-sea medusa *Periphylla hyacinthina* and other bathypelagic plankters. Perhaps these large individuals of *Sebastes* were carried upwards into strata above their usual level.

APPENDIX

Distribution of *Sebastes viviparus* and other *Sebastes* Fry with Ventral Caudal Melanophores

(Table 13)

A survey of the material collected by the R/V "Dana" in 1947/48 and 1950/58, together with two catches of *Sebastes* fry taken on the Godthaab Expedition in 1928, is given below.

The quantitative distribution of fry of *Sebastes viviparus* is shown in Figure 10, area I. This species occurs in abundance only in boreal, neritic waters (e.g. off the Faroes, Shetlands, and Iceland) and in submarine ridge areas such as the Reykjanes Ridge area. In Figure 10 the data from the Faroes are summarized. The length of the fry varied between 4 and 14 mm, the majority being 6–10 mm long.

In areas II–IV only a few specimens of *Sebastes* fry with ventral caudal pigmentation are found.

In area II, east of Greenland, one specimen, 11 mm, was taken at St. 9983 I on 6. July 1956 and nine specimens (1/9, 2/10, 3/12, 3/13 mm) were caught at St. 9986 I on 7. July 1956. These postlarvae may be either of the *S. viviparus* or of the *S. marinus mentella* type, both of which occur as adult fish in the area (Templeman, 1959).

In West Greenland waters two specimens have been caught, one, 11 mm, at St. 9996 I on 11. July 1956 and one at St. 10.942 I on 9. August 1958 (on the Frederikshåb section). These two specimens are probably of the *S. marinus mentella* type which occurs in the area in question (Templeman, 1959). Furthermore Dr. P. M. Hansen (personal communication, November 1959) after the Redfish Symposium, examined two ovaries from *Sebastes marinus* (according to his journal) caught on 2. June 1947 in the Godthåb Fjord (see Fig. 10). One female was in "spawning" condition; the ovary of the other female was quite ripe. In both ovaries larvae with caudal pigmentation were found,

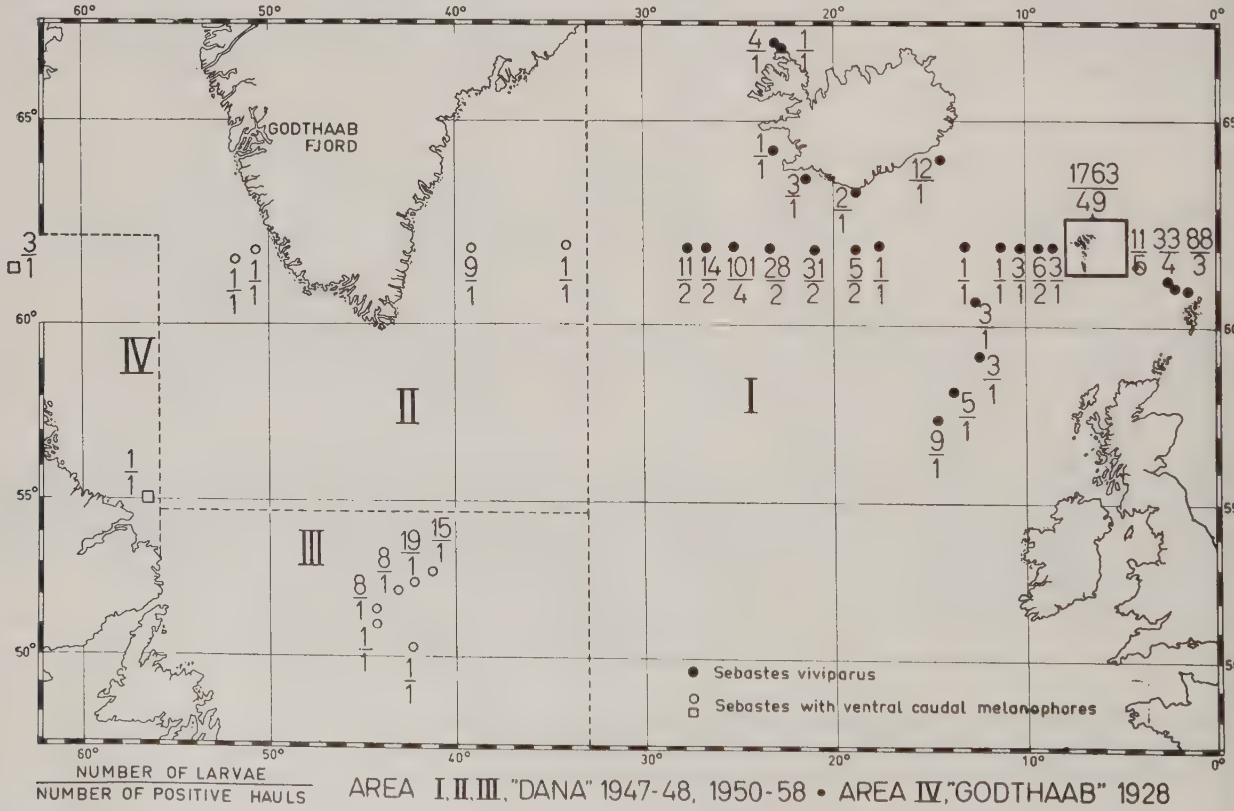
60°
50°
40°
30°
20°
10°
0°
65°
60°
55°
50°
GODTHAAB FJORD
IV
II
III
I
3/1
1/1
1/1
9/1
1/1
1/1
8/1
8/1
19/1
15/1
1/1
1/1
4/1
1/1
1/1
3/1
2/1
12/1
11/2
14/2
101/4
28/2
31/2
5/2
1/1
1/1
1/1
3/1
63/2
1763/49
11/5
33/4
88/3
3/1
3/1
5/1
9/1
● Sebastes viviparus
○ □ Sebastes with ventral caudal melanophores
NUMBER OF LARVAE / NUMBER OF POSITIVE HAULS
AREA I.II.III. "DANA" 1947-48, 1950-58 • AREA IV. "GODTHAAB" 1928

Figure 10. The quantitative distribution of fry of *Sebastes viviparus* (Area I) and of fry of *Sebastes* with ventral, caudal pigmentation (Areas II–IV).

Table 13

Number and length of fry of *Sebastes* with caudal ventral pigmentation and *S. marinus* from St. 6689—6695, NE of Newfoundland 1947

		Sebastes with pigmentation Length (mm)					*Sebastes marinus* Length (mm)							
St. No.	Date	10	11	12	13	14	9	10	11	12	13	14	15	16
6689	27. June	–	1	–	–	–	–	–	–	–	–	–	–	–
91	„	–	–	–	1	–	–	–	–	–	–	–	–	–
92	28. June	–	5	3	–	–	–	–	–	–	–	–	–	–
93	„	3	5	–	–	–	–	1	1	2	4	1	–	–
94	„	4	1	6	5	3	–	2	2	4	1	1	1	–
95	„	2	8	2	2	1	1	1	2	–	1	4	1	2
Total		9	20	11	8	4	1	4	5	6	6	6	2	2
Mean length		11·58 mm					12·50 mm							

in accordance with Templeman's figures in his contribution to the Redfish Symposium (Templeman and Sandeman, this volume, section III, p. 241).

On the Godthaab Expedition 1928, four postlarvae of *Sebastes* with caudal pigmentation were taken in area IV, three specimens of 7 mm length at St. 14 on 6. June, gear S.200, 314 m wire out, at a depth of 35 m, and one specimen, 6 mm, at St. 18 on 11. June, gear S.200, 475 m wire out, at a depth of 100 m.

There is evidence for believing that these four postlarvae were of the *S. marinus mentella* type. The occurrence is in accordance with the distribution pattern given by Templeman (1959).

Of special interest is the occurrence in area III of 52 postlarvae with caudal pigmentation. They were taken at six stations (St. 6689–95) on 27. and 28. June 1947. The identification was made by Dr. Tåning who initially distinguished them as *"Sebastes viviparus americanus"*, in view of their similarity to the European *S. viviparus* as regards the caudal pigmentation. They were readily distinguishable from fry of *S. marinus*, of which species 32 specimens taken at St. 6693–95 had a mean length of 1 mm more than the *viviparus* type. These American postlarvae might probably have been carried in the current from the Newfoundland Bank area. The depth in the area in which they were taken was more than 4,000 m (see Fig. 7). The reasons why this type has not been encountered since 1947 may be that the present section from Cape Farewell to Ireland runs too much further east, and that it is worked in late summer (August).

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8.

Continuous Plankton Records: The Distribution of Young Stages of *Sebastes*

By

G. T. D. HENDERSON

Scottish Marine Biological Association, Oceanographic Laboratory, Edinburgh

Introduction

The western limit of the Plankton Recorder Survey in the Atlantic had been for some years at approximately 20°W longitude, but a re-allocation of responsibility for weather stations from 1955 onwards resulted in the continuous occupation of station 'ALFA' (62°N, 33°W) by European ships. It thus became possible to obtain some records from British, Dutch, and Norwegian Weather Ships from the area south and southwest of Iceland. With the help and cooperation of the Department of Fisheries of the University Research Institute in Iceland, an additional route from Reykjavik towards New York was started in 1957, and its track (Z) crosses that of the Weather Ships (U) to station 'ALFA' (see Fig. 1). Young *Sebastes* were taken on these new routes in the months of April to June, at times in quite large numbers. The material available up to the end of 1958 seemed sufficient to suggest the pattern of distribution at 10 metres depth, and forms the basis of this preliminary account.

Methods

The Plankton Recorder samples at a depth of 10 metres, and filters approximately 0·3 m^3 of water per mile towed. The Records, from tows of up to 450 miles, are divided into 'blocks' or samples, each representing ten miles of tow. The area traversed by the Recorder routes has been divided into squares with sides of 1° of latitude and 2° of longitude (containing four international squares) and the occurrences of young *Sebastes* were plotted for all squares in which samples have been taken. In each square the results are expressed as the number caught per 10·0 m^3 sampled. On each of the distribution charts a "standard" rectangle is shown (bounded by the parallels of 59° and 63°N, and the meridians of 19° and 35°W) within which the majority of the *Sebastes* were found; this standard area has been used in examining the relative abundance in the different months and years.

The identity of the young stages

The original identifications were recorded as *Sebastes* spp. because of doubts about the specific validity of *S. mentella,* and lack of knowledge of the detail differences in the pigmentation of the young of *S. marinus* and *S. viviparus* (see Tåning, 1949, p. 86). Through the courtesy of Mr. A. Saville of the Scottish Home Department's Marine Laboratory of Aberdeen, it has been possible to use copies of a key and of drawings of some of the young stages of *S. marinus* and *S. viviparus* prepared by the late Dr. Tåning, but which have not been published until now (this section, p. 234). With the help of these, about half the *Sebastes* caught have been checked, by re-examining those on alternate, odd numbered, blocks. Using Tåning's criteria, all those examined agree with the description of young *Sebastes marinus*; none show the pigment spots below the tip of the notochord which were stated to be characteristic of *S. viviparus*. The observation that the spines on the head appear to be slow in development and less prominent than in *S. viviparus* supports the belief that the Recorder catches are *S. marinus.* Additional support for this view is provided by the differences in pigmentation between *marinus*-type and *mentella*-type larvae described by Templeman and Sandeman (1959).

The seasonal distribution

With the exception of two large specimens (28 and 30 mm) taken in July 1958, no young *Sebastes* have been identified from the Plankton Records in any months except April, May, and June, and none have yet been identified from routes crossing the area between the British Isles and the longitude of 19°W. The distribution of these young stages at the 10 metre level, in each of these months, is shown in Figure 2. In April only small numbers were taken, the majority on a 'U' record late in the month in 1955. Very few were obtained during April in the following three

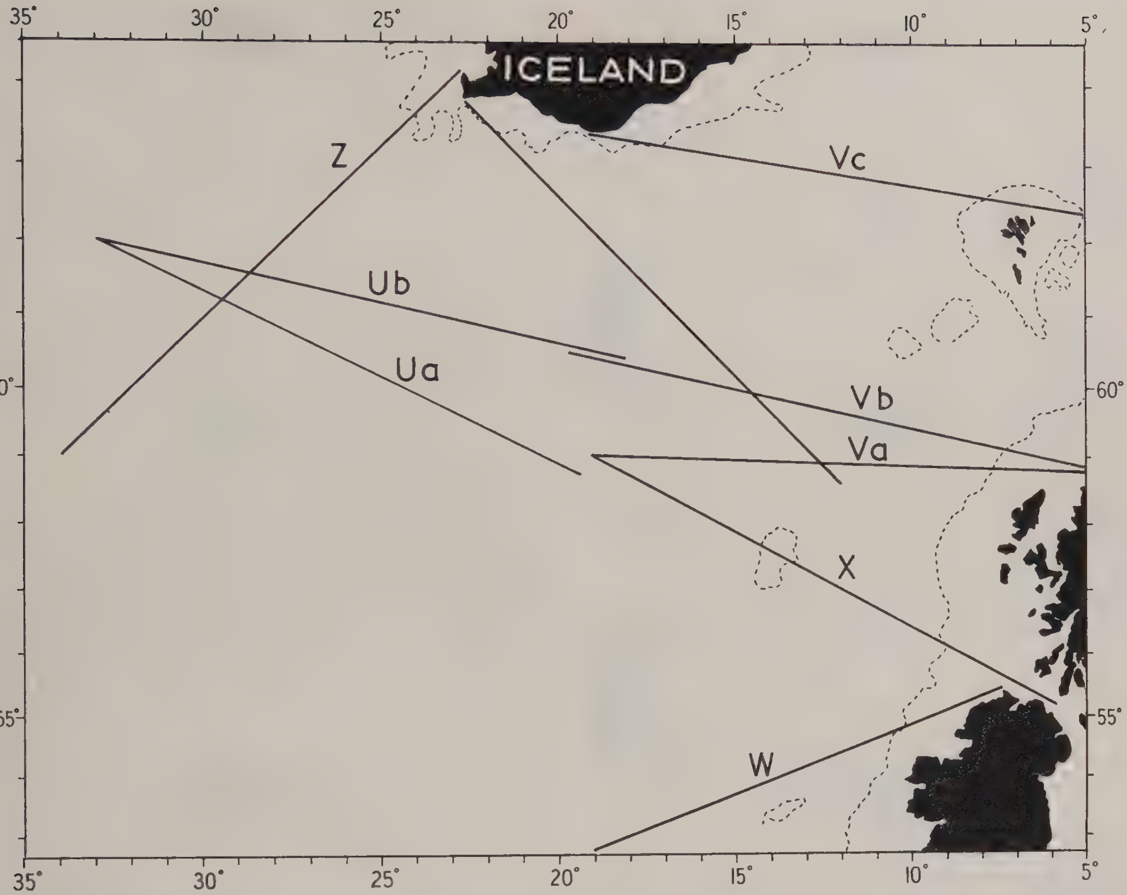

Figure 1. Chart showing the Continuous Plankton Recorder routes in the Atlantic between the British Isles and Iceland. The letters identify the routes, but they are not all sampled in every month, as some are alternative tracks to Weather Ship Stations.

years; all were taken west of 25°W Long. and most occurred within the limits of 59° to 61°N, and 25° to 31°W. The mean number of young within the standard rectangle in April was 0·8 per 10 m^3 of water.

Much greater numbers were taken in May, particularly in 1957, the highest numbers lying between 59° and 62°N and 29° and 35°W. The limits of the distribution were further to the north and east than in April, with some taken outside the standard rectangle west of Reykjanes, and a few outside the south-east corner. The mean number in the rectangle was 2·4 per 10 m^3. There is no evidence so far to suggest any spreading to the north-east as might be inferred from the distribution outlined by Tåning (1949, p. 91), but the Recorder samples were from the 10 metre level only, so that if the larger individuals tend to inhabit deeper layers they would not be sampled.

By June the numbers taken had fallen, although they were more numerous than in April, with 1·4 per 10 m^3 in the rectangle. There appeared to be some tendency for the larger numbers to occur at the south-east corner of the rectangle, but the unfortunate absence of records in June on the 'Z' route, with the consequent inadequate sampling of the western part of the rectangle, diminishes considerably the value of this observation.

The annual distribution

No attempt has been made to achieve precision in the estimation of fluctuations in abundance and distribution which may have occurred from year to year, as the material is considered insufficient for this purpose, but some comments are offered on the distribution in the years 1956–1958, shown in Figure 3. In these charts all the samples in the months of April, May, and June have been combined for each year; 1955 has been omitted, as the sampling depended on a 'U' record in April only. Note, however, that the number per unit volume for April 1955 equalled the figure for all three months in 1956, being 1·2 per 10 m^3 in the standard rectangle. In 1956 the sampling was some-

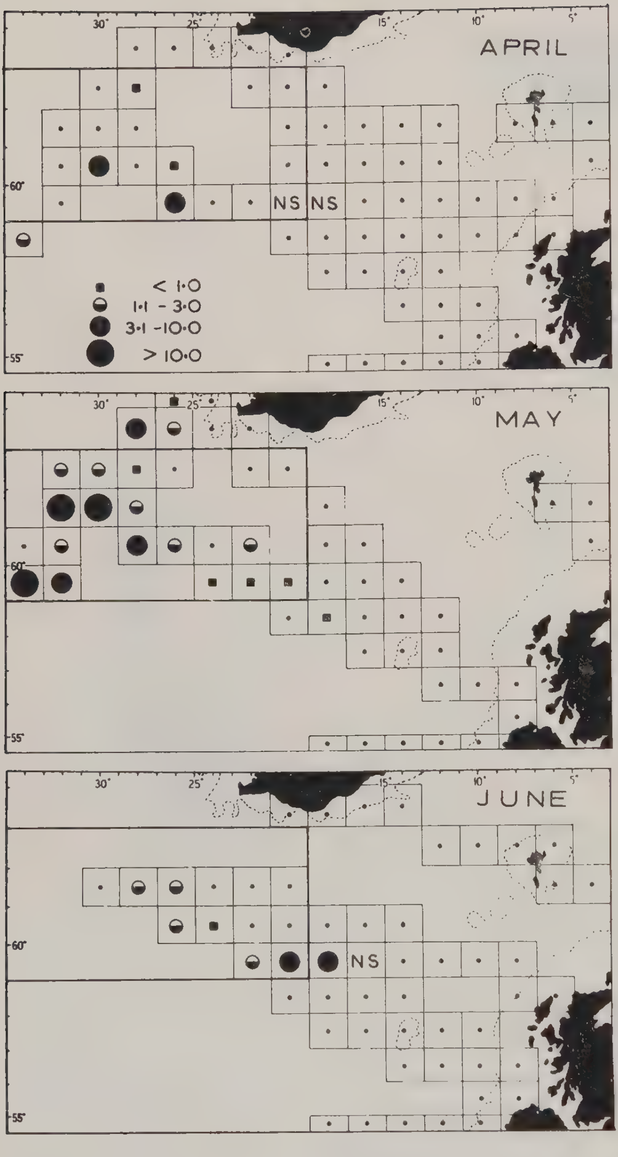

Figure 2. Charts showing the distribution of young *Sebastes marinus* for the months of April, May, and June. The symbols indicate the numbers per 10 m^3 for each square, the smallest dot showing absence. Squares which are outlined but have not been sampled are distinguished by the letters NS. In the April chart samples from 1955 to 1958 were combined; the May and June charts were produced from a combination of the material in these months in 1956, 1957, and 1958. The standard rectangle is outlined on each chart.

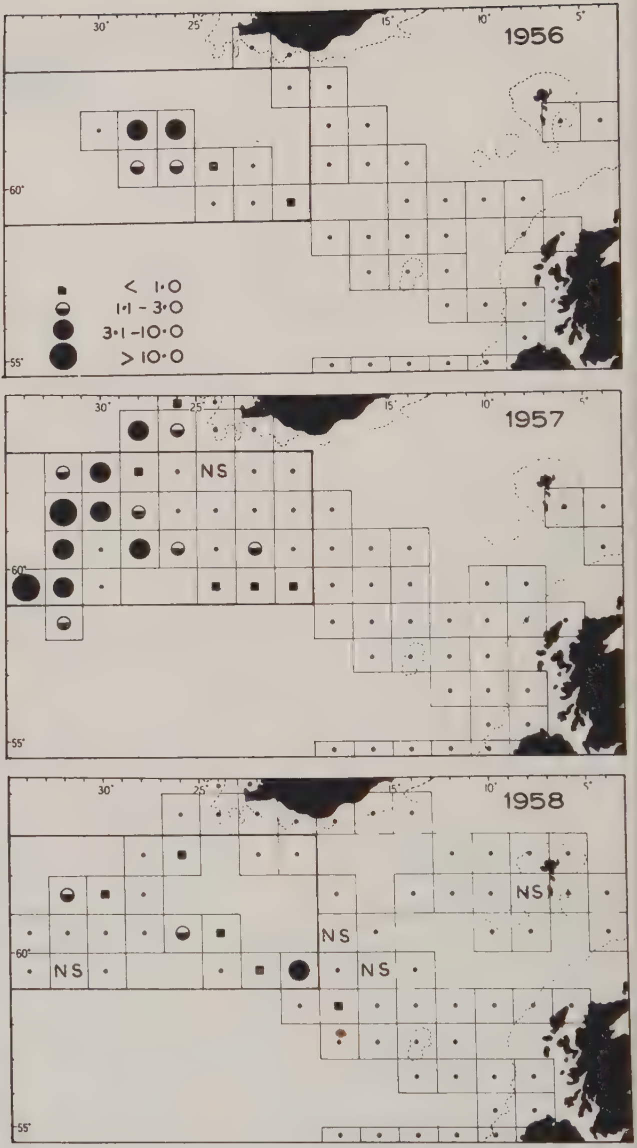

Figure 3. Charts showing the distribution of young *Sebastes marinus* during the months April, May, and June for the years 1956, 1957, and 1958. The symbols indicate the numbers per 10 m^3 for each square, the smallest dot showing absence. Squares which are outlined but have not been sampled are distinguished by the letters NS. The year 1955 is not included as the sampling was limited to April only. The standard rectangle is outlined on each chart.

what better than in 1955, but the western half of the rectangle was sparsely sampled.

In 1957 the records from the 'Z' route extended the sampling to almost the whole of the rectangle, and the numbers taken were considerably higher than in 1956, on the 'U' as well as on the 'Z' route. Eight squares in the standard rectangle show numbers of over 3·0 per 10 m^3 of which two exceeded 10 per 10 m^3. The overall figure for the rectangle was 2·9 per 10 m^3.

By comparison 1958 must be considered a poor year, as in only one square was the number over 3·0 per 10 m^3, and the overall figure in the standard rectangle was only 0·7 per 10 m^3.

The Recorder results suggest that young redfish were more abundant in 1957 than in 1956. The limited sampling in 1956 may, however, be the cause of this difference, as in net hauls on station 'ALFA' in April and May from 1955 to 1958 the largest numbers were taken in 1956 (J. Corlett, p. 194 this section). The fall in numbers from 1957 to 1958, however, may be a rather better indication of a change in abundance, as the sampling in both these years was more complete. A drop in numbers of young redfish was also reported in ICNAF Newsletter No. 30 (December 1958), only about 2 % of the 1957 numbers being reported from observations in July–August 1958. It is probably too early to assess the value of the Recorder results as indications of fluctuations, as it is believed that only one "sector" of the distribution has been sampled. Reference to the May chart in Figure 2, and to the 1957 chart in Figure 3, shows the possibility that the distribution may extend further to the south and west outside the range of the Recorder survey. In 1959 (with the assistance of the Reykjavik Fisheries Laboratory) the sampling on the 'Z' route was extended south-westwards. A preliminary inspection of the first extended records (in May, June, and July 1959) shows that young *Sebastes marinus* were caught up to 500 miles to the south-west of the standard rectangle used in this report.

A more complete account of the distribution of young redfish is being prepared for publication in Volume V of the "Bulletins of Marine Ecology", and this will include a full consideration of the material collected up to 1960, with observations on the size range of the young stages taken.

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9.

Vertical Distribution of Young Redfish in the Gulf of Maine

By

GEORGE F. KELLY and ALLAN M. BARKER

Bureau of Commercial Fisheries Biological Laboratory, Woods Hole, Massachusetts, U.S.A.

Introduction

Geographical distribution

Exploratory fishing by research and commercial vessels of several European and North American nations has extended our knowledge of distribution of redfish (*Sebastes marinus*) in all of the North Atlantic Ocean. This species is exploited by one country or another on virtually all deep-water banks from the Gulf of Maine in the south-west to the coast of Norway and the Barents Sea banks in the east. Although adult redfish are found primarily as bottom dwellers on the slopes of the continental shelf, diurnal variations in availability in some areas suggest that they sometimes rise above the bottom an undetermined distance. There is strong evidence that some adult redfish live pelagically at intermediate depths over certain areas of the deep ocean. The possibility that these may represent a very large pelagic population inhabiting vast areas of the ocean is perhaps the most important distributional question of the moment.

The existence of a pelagic population of adult redfish over deep water was first proposed by Nansen (1886). He found fresh specimens of redfish in the stomachs of hooded seals caught in the middle of the Arctic Ocean over depths of 1,500 fms. The redfish could only have been captured near the surface. Hjort (1900) confirmed Nansen's theory by catching considerable numbers of redfish on floating lines set at 100–200 m over very deep water in many parts of the Norwegian Sea. More recently the presence of great numbers of larvae at the surface hundreds of miles from the nearest known bottom-dwelling redfish stock suggests that the larvae originated from a pelagic population. However, there have been no collections of pelagic adults in these areas to substantiate the existence of a large midwater population. Evidence is needed from experimental midwater fishing to establish the size and distribution of such a population.

The pelagic larvae of *Sebastes* have been collected at many locations across the North Atlantic, but little is known of the duration of the pelagic period and the rate of growth, habits and distribution of young redfish during that time. The early life history is important in considering the definition of redfish stocks, since the distance of larval transport by water currents can affect profoundly the degree of intermingling of progeny from geographically separated stocks. The depth at which females release the living larvae and the relationship of these larvae to bottom-dwelling stocks is not known. Newly-spawned larvae (5 to 6 mm) first appear at the surface in late spring. Specimens ranging between 5 and 20 mm have been frequently collected during the summer in the upper 10 to 20 m of water in many areas. Beyond this size the young fish become less available to sampling gear until they again appear on the bottom in early autumn at a length of about 50 mm. Estimates by various investigators of the length of the pelagic period, based on these data, have ranged from a few months to more than a year. None of the estimates was supported by direct evidence from a series of length measurements of collected specimens. The comparative scarcity of young between 20 and 50 mm in earlier collections left a gap that could only be satisfactorily bridged through the investigation of the natural history of fish of that size.

Review of earlier larval studies

In the eastern Atlantic, *Sebastes* larvae were collected from the waters west and south of Iceland by Schmidt (1904) and Jensen (1922). Schmidt found large numbers of larvae in Denmark Strait during May and June 1903. Jensen found them similarly abundant in the same general area five years later. He recorded adult redfish as being widely distributed along the west coast of Greenland and in Davis Strait, but he concluded that this species does not breed in that area. No *Sebastes* larvae were taken in his plankton collections during spring and summer. It was not until late September that small fish (27–43 mm) appeared. He considered these to be the young spawned in the Denmark Strait which had drifted with the current around Cape Farewell to the south-west coast of Greenland. The distance traversed would be more than 500 miles.

Some years later Jensen (1926) altered his hypothesis of larval drift when he found young redfish along the west coast of Greenland. The specimens were sufficiently plentiful and of the proper size (7–17 mm) to have been spawned close by the collecting stations. While this new information removed the need for the hypothesis of extended larval drift to explain the presence of redfish in the Davis Strait region in 1925, it did not invalidate Jensen's original hypothesis that such an extended larval drift had indeed occurred in 1908–09.

Tåning (1949) summarized the extensive collections of the R/V "Dana" and reviewed the earlier studies in the light of his own findings. He agreed that Jensen's theory of larval drift to West Greenland was probably correct for certain periods of years, but he was not satisfied that larval drift alone could explain the occurrence of tremendous numbers of larvae over deep water at long distances from the nearest fishing banks. He felt that the presence of suitable hydrographic conditions over a wide area suggested the existence of a "pelagic high boreal community" of adult redfish distributed at mid-depths over the deep water nearby where larvae were found. Tåning was convinced that the pelagic population was of tremendous size and could eventually support a substantial commercial fishery.

In the western Atlantic, redfish larvae have been taken virtually everywhere that adults occur. Bigelow (1914 and 1917) reported larval redfish to be the most commonly recurrent fish species in the Gulf of Maine plankton in the summers of 1912–1915. They were usually found between the coast and the 200 m contour. Dannevig (1919) found redfish larvae to be numerous in the Gulf of St. Lawrence and on the Nova Scotian banks during 1914–1915, mainly along the edges of banks adjacent to deep water. Frost (1938) reported redfish larvae at many stations in the Gulf of St. Lawrence and around Newfoundland in spring and autumn during 1931 to 1935. Steele (1957) recorded the presence of larvae along the Gaspé coast in the Gulf of St. Lawrence.

The point that seems to characterize the findings of eastern Atlantic studies is that large numbers of larvae appear to be concentrated at the surface in some areas where adult *Sebastes* are not known to occur. Conversely, in some years no larvae are collected in regions where large redfish are abundant. On the other hand, in no instance have western Atlantic studies shown larvae to be present where adult redfish do not occur. If these differences are real, it is not possible to say whether they result from different spawning behaviour of adults in the two areas, or are, perhaps, the result of fundamentally different hydrographic systems influencing larval distribution.

In earlier studies on both sides of the Atlantic, the emphasis was on numbers of larvae encountered, with little regard for specific depth of the catch or sizes of larvae collected. Many collections were from vertical or oblique hauls taken from a specified depth to the surface.

There are relatively few records of redfish greater than 20 mm in length that were collected in plankton nets. Jensen (1926) listed several specimens ranging as large as 49 mm taken in his ring-trawls, but the bulk of his collections were of larvae smaller than 20 mm. Tåning (1949) mentions an upper limit of 21 mm, in citing the size range of almost 1,100 larvae taken in a single haul of the 2 m stramin net. Dannevig (1919) illustrates redfish larvae ranging from a 5·6 mm larva to a 20 mm postlarva, citing only the mid-length of each station collection in the text. Although Frost (1938) did not list sizes, her data from collections of the R/V "Cape Agulhas" were summarized in a table by Perlmutter and Clarke (1949). Of more than 600 specimens in her collections, only three exceeded 20 mm, the largest being 37 mm. Bigelow (1914 and 1917) cites five stations where the size range exceeded 20 mm, but the number of specimens of greater size is not stated. He described the concentration of larvae at one station as a "swarm" ranging from 14 to 40 mm. This probably contained many fish larger than 20 mm.

There was no specifically directed effort to examine the vertical distribution of the larvae in any of the studies cited. Perhaps it was presumed by earlier workers that once the fish reached 20 mm they quickly settled to the bottom wherever they chanced to be. Experience while bottom trawling in the Gulf of Maine (Kelly and Wolf, 1959) reveals the youngest age-group (pre-annulus) ranging between 35 and 55 mm and averaging 48 mm in length in November. A comparison of the size range sampled by plankton nets and taken in the bottom trawls suggests that larger postlarvae have been virtually unsampled in most previous studies. Special studies of factors affecting the 20 to 60 mm young seemed necessary before theories of larval drift could be considered in proper perspective. With this purpose in mind, a programme of midwater trawling was planned for the Gulf of Maine in 1957 and 1958.

Objectives

The purpose of the study was to test the effectiveness of the midwater trawl for sampling young redfish in late summer, to determine their pelagic distribution, abundance and growth-rate during the pelagic period. Specific objectives were to:

(1) determine the horizontal and vertical distribution of young redfish with respect to water temperature;

(2) measure relative abundance of young redfish;

(3) examine diurnal variations in depth distribution and abundance of young;

(4) determine growth-rate of young from changes in size composition during the pelagic stage, to validate the computed age at first year-zone formation in scales and otoliths;

(5) estimate the duration of the pelagic period.

Methods

Study area

This paper is the result of field work done on four cruises of the R/V "Albatross III" in late July and early September of 1957 and 1958. In 1957 a series of midwater stations were sampled in the south-western part of the Gulf of Maine, an area where a fairly large brood-stock of redfish was known to exist (Fig. 1). The station locations were selected, using the records of Bigelow's early catches as a starting point, allowing freedom for exploratory fishing in areas that appeared promising (Table 1). On the basis of the success of the 1957 sampling, the 1958 programme duplicated the sampling as a check on the relative strength of the new year-class (Table 2).

Description of fishing gear

The 10 ft Isaacs-Kidd midwater trawl was used as the sampling gear because it is well suited for the high-speed collection of small fish (Isaacs and Kidd, 1953). The outstanding feature of this trawl is that no towing cables cross in front of the mouth of the net to frighten or interfere with animals in its path. The trawl was rigged with a Leavitt (1935) net-releasing device operating as an opening-and-closing net to minimize the contamination of collections while setting and retrieving the gear. The entire net was lined with $^{3}/_{8}$ inch (stretched mesh) cotton netting capable of retaining redfish as small as 10 mm.

A cod-end with $^{3}/_{8}$ inch mesh was used on all cruises except No. 117 in September 1958. At that time the fish taken in the first few tows were fewer and much smaller than those caught at the same time the previous year. A cod-end consisting of stramin netting was added to retain any smaller fish that might escape. This mesh retains fish as small as the new-born 5 mm redfish larvae.

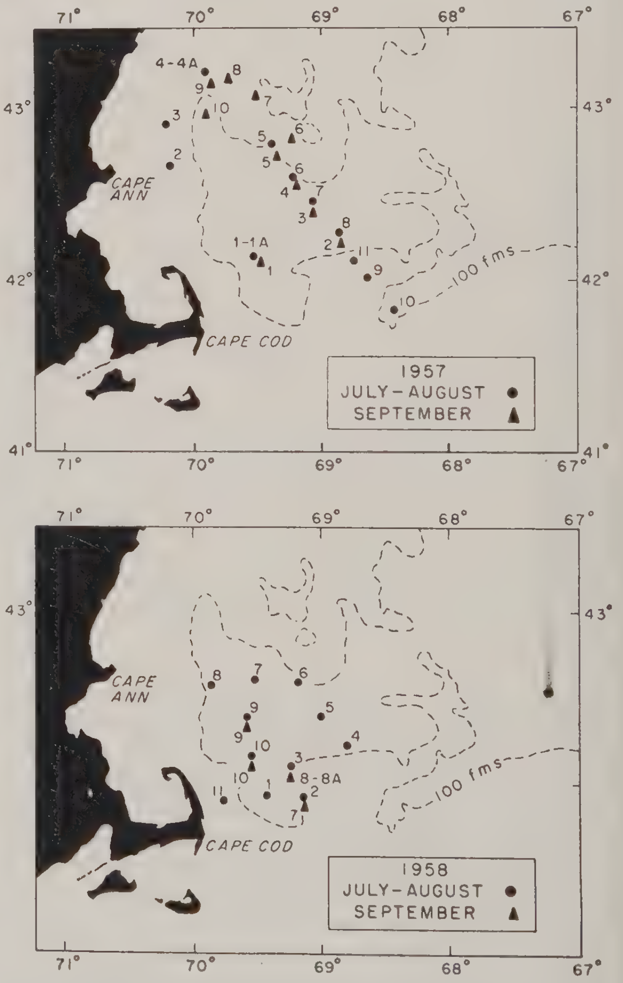

Figure 1. Redfish midwater trawl stations occupied in the Gulf of Maine in 1957 and 1958. (For clarity the cruise numbers have been omitted from the figure – see Tables 1 and 2 for complete station designation.)

Depth calibration of the gear

At the outset of operations the net was run through a series of calibration tows, to determine the relationship of the length of trawl warp to depth of net in the water. A telemetric depth recorder (Boden, *et al.*, 1955) was used for calibration.

The trawl was towed at a series of ten depths from the surface to 150 m. Depth was checked on the tele-

Table 1

Summary of 1957 collections. The number of redfish and number of midwater trawl tows are listed by depth for each station

(Number of tows in parentheses)

“Albatross III” – Cruise Number 99

Station Number	Lat. N	Long. W	Date of collection 1957	Depth (m)	Surface water temperature °F	°C
99–1	42°08′	69°30′	July 26–27	233–264	66·2	19·0
99–1A	42°08′	69°30′	Aug. 1	233–264	–	–
99–2	42°43′	70°10′	July 28	123–143	63·6	17·6
99–3	42°55′	70°13′	July 28	141–187	65·4	18·6
99–4	43°12′	69°55′	July 29	163–176	–	–
99–4A	43°09′	69°48′	July 30	220	67·4	19·6
99–5	42°47′	69°21′	July 30	224–246	66·3	19·1
99–6	42°35′	69°11′	July 30	268–290	66·2	19·0
99–7	42°37′	69°04′	July 31	257–299	66·0	18·9
99–8	42°15′	68°51′	July 31	268	66·0	18·9
99–9	42°01′	68°38′	July 31	207	66·7	19·3
99–10	42°49′	68°25′	July 31	246	–	–
99–11	42°10′	68°45′	July 31– Aug. 1	231–251	66·6	19·2

“Albatross III” – Cruise Number 102

Station Number	Lat. N	Long. W	Date of collection 1957	Depth (m)	Surface water temperature °F	°C
102–1	42°08′	69°30′	Sept. 5–6	233–264	64·6	18·1
102–2	42°15′	68°51′	Sept. 6	268	65·0	18·3
102–3	42°27′	69°04′	Sept. 6–7	257–299	64·8	18·2
102–4	42°35′	69°11′	Sept. 7	268–290	–	–
102–5	42°44′	69°19′	Sept. 7–8	231–275	–	–
102–6	42°49′	69°15′	Sept. 8	198	–	–
102–7	43°06′	69°33′	Sept. 9	176–180	60·0	15·5
102–9	43°09′	69°52′	Sept. 9	198	60·2	15·6
102–10	42°57′	69°55′	Sept. 9	198	–	–

“Albatross III” – Cruise Number 99 – July–August

Station Number	Surface	Depth in metres 10	20	30	40	60	80	100	110	Total
99–1	–	6(3)	440(3)	21(4)	7(3)	24(3)	–	1(2)	–	499(18)
99–1A	–	49(2)	58(2)	36(1)	–	–	–	–	–	143(5)
99–2	–	3(2)	2(2)	0(2)	0(2)	–	–	–	–	5(8)
99–3	0(1)	0(2)	3(2)	0(2)	1(2)	0(1)	–	–	–	4(10)
99–4	0(1)	25(2)	49(2)	0(1)	1(1)	0(1)	–	–	–	75(8)
99–4A	–	–	1(1)	–	–	–	–	–	–	1(1)
99–5	–	1(2)	7(2)	9(2)	2(2)	–	–	–	–	19(8)
99–6	–	82(1)	1990(1)	–	–	–	–	–	–	2072(2)
99–7	–	–	582(1)	–	–	–	–	–	–	582(1)
99–8	–	–	560(1)	–	–	–	–	–	–	560(1)
99–9	–	–	31(1)	–	–	–	–	–	–	31(1)
99–10	–	0(1)	0(1)	0(1)	0(1)	–	–	–	–	0(4)
99–11	–	113(2)	138(2)	30(2)	12(2)	6(1)	–	–	–	299(9)
Total	0(2)	279(17)	3861(21)	96(15)	23(13)	30(6)	–	1(2)	–	4290(76)

“Albatross III” – Cruise Number 102 – September

Station Number	Surface	10	20	30	40	60	80	100	110	Total
102–1	–	9(2)	6(2)	5(2)	9(2)	–	–	–	–	29(8)
102–2	–	4(1)	0(1)	0(1)	0(1)	–	–	–	–	4(4)
102–3	–	8(2)	6(2)	1(2)	45(2)	16(1)	29(2)	282(2)	177(1)	564(14)
102–4	–	0(1)	14(1)	1(1)	2(1)	–	0(1)	0(1)	1(1)	18(7)
102–5	–	88(2)	51(2)	17(1)	2(1)	4(1)	387(1)	220(1)	0(1)	769(10)
102–6	–	4(1)	0(1)	–	0(1)	–	–	12(1)	–	16(4)
102–7	–	5(1)	0(1)	–	0(1)	–	0(1)	0(1)	–	5(5)
102–9	–	0(1)	0(1)	–	–	–	–	1(1)	–	1(3)
102–10	–	3(1)	6(1)	–	0(1)	0(1)	14(1)	9(1)	–	32(6)
Total	–	121(12)	83(12)	24(7)	58(10)	20(3)	430(6)	524(8)	178(3)	1438(61)

Table 2

Summary of 1958 collections. The number of redfish and number of midwater trawl tows are listed by depth for each station

(Number of tows in parentheses)

"Albatross III" – Cruise Number 116

Station Number	Lat. N.	Long. W	Date of collection 1958	Depth (m)	Surface water temperature °F	°C
116–1	41°55′	69°30′	July 28–29	238–255	63·7	17·6
116–2	41°56′	69°12′	July 29	260–275	64·3	17·9
116–3	42°07′	69°12′	July 29–30	238–245	64·9	18·3
116–4	42°15′	68°51′	July 30	268	64·4	18·0
116–5	42°27′	69°04′	July 30	257–299	64·1	17·8
116–6	42°35′	69°11′	July 30	268–290	64·5	18·1
116–7	42°33′	69°31′	July 31	330–339	64·9	18·3
116–8	42°32′	69°48′	July 31	282–304	62·6	17·0
116–9	42°21′	69°36′	July 31	282–315	64·9	18·3
116–10	42°09′	69°35′	July 31– Aug. 1	273–304	65·1	18·4
116–11	41°52′	69°48′	Aug. 1	158	–	–
"Albatross III" – Cruise Number 117						
117–7	41°56′	69°12′	Sept. 14	260–275	61·5	16·4
117–8	42°07′	69°12′	Sept. 14	238–245	60·6	15·9
117–8A	42°07′	69°12′	Sept. 15–16	238–246	60·6	15·9
117–9	42°21′	69°36′	Sept. 15	282–315	61·4	16·3
117–10	42°09′	69°35′	Sept. 15	273–304	61·0	16·1

"Albatross III" – Cruise Number 116 – July–August

Station Number	Depth in metres									
	Surface	10	20	30	40	60	80	100	110	Total
116–1	–	0(2)	0(1)	0(1)	0(1)	0(1)	0(1)	–	–	0(7)
116–2	–	1(1)	1(1)	0(1)	0(1)	0(1)	0(1)	–	–	2(6)
116–3	–	1(1)	1(1)	0(1)	0(1)	0(1)	–	–	–	2(5)
116–4	–	2(1)	3(1)	–	0(1)	–	–	–	–	5(3)
116–5	–	11(1)	1(1)	0(1)	0(1)	0(1)	0(1)	–	–	12(6)
116–6	–	1(1)	1(1)	0(1)	0(1)	–	–	–	–	2(4)
116–7	0(1)	0(1)	0(1)	0(1)	–	–	–	–	–	0(4)
116–8	–	0(1)	1(1)	0(1)	–	–	–	–	–	1(3)
116–9	–	17(2)	22(2)	0(1)	–	–	–	–	–	39(5)
116–10	–	0(1)	1(1)	0(1)	0(1)	–	–	–	–	1(4)
116–11	–	6(1)	8(1)	–	–	–	–	–	–	14(2)
Total	0(1)	39(13)	39(12)	0(9)	0(7)	0(4)	0(3)	–	–	78(49)
"Albatross III" – Cruise Number 117 – September										
117–7	–	12(1)	4(1)	4(1)	1(1)	0(1)	0(1)	–	–	21(6)
117–8	–	10(1)	–	–	–	–	–	–	–	10(1)
117–8A	–	146(1)	31(1)	7(1)	6(1)	–	0(1)	–	–	190(5)
117–9	–	36(1)	0(1)	1(1)	0(1)	–	1(1)	–	–	38(5)
117–10	–	2(1)	0(1)	0(1)	–	1(1)	0(1)	–	–	3(5)
Total	–	206(5)	35(4)	12(4)	7(3)	1(2)	1(4)	–	–	262(22)

metric recorder and the amount of trawl warp passing over a metered wheel was recorded at each depth. This was done at about 4½ knots vessel speed. A curve was drawn to the points, and standard trawl warp lengths were taken from the curve for 10 metre intervals from the surface to 110 m. In all subsequent operations the trawl was set by paying out on the metered wheel the standard trawl warp length required for a desired depth, after which speed, measured by engine RPM's, was kept constant.

Station procedure

At each station, a series of 1 hr tows was made at 10, 20, 30, and 40 m. If large numbers of redfish were found, the entire series was repeated a second or third time to determine whether diurnal variations occur in the vertical distribution of the larvae. Occasionally the series was extended to 60, 80, 100, and 110 metres.

The net was set to the desired depth in the closed position, opened with the first messenger, and towed for one hour. The second messenger closed the net and it was then retrieved. The number of tows made at the various depths on each cruise is shown in Tables 1 and 2. Fishing effort was not evenly distributed among the depths on any of the cruises. A standard bathythermograph cast was made at each station.

Results

Abundance

The number of larvae collected in 1957 was almost twenty times greater than in 1958 (Tables 1 and 2). Catch-per-tow by depth shows the highest relative abundance of young fish at 20 m in July–August and at 80–100 m in September 1957 (Table 3). In 1958 the small numbers taken were mainly in the 10–30 m zone. Admittedly, the high and low relative abundances of the 1957 and 1958 year-classes afford no basis for quantitative evaluation of average relative abundance of young-of-the-year redfish. However, judged from previous experience in sampling young redfish in the same area with plankton nets and small-mesh otter trawls, the large numbers of young available in 1957 suggest that larval survival in that year was above average, and that 1958 survival was below average.

Observed water temperatures were similar during the two years. Minor differences were detected, but it appears unlikely that these could cause such great variation in the success of spawning or of larval survival. The apparent failure of the 1958 year-class seems more likely the result of other causes.

Distribution

In July–August 1957 most of the redfish were found in the area south of Cape Ann (Fig. 1). A month later the greatest numbers were still in this region, but they appeared to be concentrated along the easterly side of the deep water (stations 102–103 and 102–105). In 1958, the sampling was confined to the southern area, and, although the fish were scarce, in July–August the largest numbers of larvae were taken in the same general area as in 1957.

The 1957 samples indicated that a significant change in depth distribution had occurred between July–August and September. About 98 % of the fish were caught between 10 and 30 m in July–August (Table 1). In September, the fish were taken deeper and 80 % of the catch was from depths of 80 to 110 metres.

The 1958 data are generally similar in that July–August larvae were found at 10 and 20 metres, while the September distribution included a few specimens as deep as 80 m (Table 2). However, 1958 does not show the spectacular change in vertical distribution of larvae that was observed in 1957.

The vertical distribution of larvae with respect to water temperature showed some interesting differences. In July–August 1957, all of the large catches were taken within the thermocline (Fig. 2). It is surprising that the larvae should remain in this area of high temperature gradient where it would appear that they might be exposed to changes of 6° to 15°F. Perhaps their position in the thermocline is advantageous since it enables them to select a preferred temperature with a minimum of vertical movement in the water column.

In September 1957, most of the fish were found in cool water well below the thermocline. This water was almost isothermal from a point just below the thermocline to the bottom.

Table 3

Summary of fishing effort and mean catch per tow, by depth, 1957—1958

Depth (m)	July–August 1957			September 1957			July–August 1958			September 1958		
	Number of tows	Number of fish	Catch per tow	Number of tows	Number of fish	Catch per tow	Number of tows	Number of fish	Catch per tow	Number of tows	Number of fish	Catch per tow
Surface	2	0	0·0	–	–	–	1	0	0·0	–	–	–
10	17	279	16·4	12	121	10·0	13	39	3·0	5	206	41·2
20	21	3861	183·8	12	83	6·9	12	39	3·3	4	35	8·8
30	15	96	6·5	7	24	3·4	9	0	0·0	4	12	3·0
40	13	23	1·8	10	58	5·8	7	0	0·0	3	7	2·3
60	6	30	5·0	3	20	6·7	4	0	0·0	2	1	0·5
80	–	–	–	6	430	71·7	3	0	0·0	4	1	0·3
100	2	1	0·5	8	524	65·5	–	–	–	–	–	–
110	–	–	–	3	178	59.3	–	–	–	–	–	–
Total	76	4,290		61	1,438		49	78		22	262	
Mean catch per tow			56·4			23·6			1·6			11·9

Table 4

Summary of numbers of redfish by depth and hour of day captured (Eastern Daylight Time)

Cruise Number 99 – July–August 1957

Depth in metres			Hours				Sunrise			Hours		
	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100
10	0	–	–	–	97	–	1	–	3	23	3	0
20	583	–	0	–	560	49	–	31	0	–	2	347
30	13	–	0	–	0	–	–	21	–	–	0	0
40	–	9	1	–	1	–	0	–	–	3	–	0
60	–	–	–	6	22	0	–	–	–	–	–	–
100	–	–	–	–	–	–	–	–	–	–	–	–
Total	596	9	1	6	680	49	1	52	3	26	5	347

Depth in metres			Hours						Sunset				
	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	Total
10	–	–	49	0	–	–	–	16	87	–	–	–	279
20	0	–	–	–	7	22	–	–	36	145	2079	–	3861
30	0	17	0	–	–	9	36	–	–	–	–	–	96
40	–	0	0	6	–	1	2	0	–	–	–	–	23
60	–	–	–	–	2	–	–	0	–	–	–	–	30
100	–	–	–	–	–	1	0	–	–	–	–	–	1
Total	0	17	49	6	9	33	38	16	123	145	2079	–	4290

Cruise Number 102 – September 1957

Depth in metres			Hours				Sunrise			Hours		
	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100
10	8	–	5	–	0	–	5	–	–	–	4	–
20	3	1	–	0	–	3	–	11	–	–	–	14
30	–	2	–	0	–	–	3	–	–	–	–	–
40	–	0	–	9	18	0	–	–	–	–	–	–
60	4	–	0	–	–	16	–	–	–	–	–	–
80	–	–	387	14	–	–	–	0	–	–	–	–
100	12	–	–	220	9	–	0	–	0	–	–	–
110	–	–	–	–	0	–	–	–	–	–	–	–
Total	27	3	392	243	27	19	8	11	0	–	4	14

Depth in metres				Hours					Sunset				
	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	Total
10	–	–	–	–	0	0	–	–	87	–	3	9	121
20	–	–	–	–	–	5	0	–	–	40	–	6	83
30	1	–	–	–	–	–	1	–	–	–	17	–	24
40	–	2	–	–	–	–	–	27	–	–	0	2	58
60	–	–	–	–	–	–	–	–	–	–	–	–	20
80	–	–	–	0	–	–	–	–	–	–	29	–	430
100	–	–	–	–	0	–	–	1	–	282	–	–	524
110	–	–	–	–	–	1	–	–	–	–	–	177	178
Total	1	2	–	0	0	6	1	28	87	322	49	194	1438

The temperature profiles taken at stations yielding large and small catches of young fish were generally similar each month in 1957 (Fig. 2). In July–August 1957, the areas of larval abundance showed less clearly defined thermoclines. However, it would be difficult to determine if the larvae seek a lower temperature gradient, or whether the currents that serve to concentrate the larvae also function to disperse the thermocline and reduce the temperature gradient. Despite variations of a few degrees in surface temperature, the range of temperatures in the thermocline was similar, and the temperature of the deep isothermal water was nearly the same in both years.

Diurnal variations

Diurnal variations in numbers of fish were evident in the 1957 samples (Table 4). Eighty-seven per cent. of the total number of fish caught in July–August 1957 were taken between twilight (1800) and daybreak (0600). In September 1957, 96 % of the larvae were

Table 5
Summary of fishing effort and mean catch per tow by time of day (Eastern Daylight Time)

	Time of day	Total number of tows	Number of tows with redfish	Number of redfish	Mean catch per tow
1957					
July–August					
Cruise No. 99	0600–1200	17	11	434	25·5
	1200–1800	25	9	114	4·6
	1800–0000	14	12	2401	171·5
	0000–0600	20	12	1341	67·0
Total		76	44	4290	56·4
September					
Cruise No. 102	0600–1200	12	7	37	3·1
	1200–1800	10	3	9	0·9
	1800–0000	16	12	681	42·6
	0000–0600	23	16	711	30·9
Total		61	38	1438	23·6
1958					
July–August					
Cruise No. 116	0600–1200	13	6	28	2·2
	1200–1800	9	3	40	4·4
	1800–0000	12	4	4	0·3
	0000–0600	15	3	6	0·4
Total		49	16	78	1·6
September					
Cruise No. 117	0600–1200	7	5	22	3·1
	1200–1800	8	4	14	1·8
	1800–0000	4	2	184	46·0
	0000–0600	3	2	42	14·0
Total		22	13	262	11·9

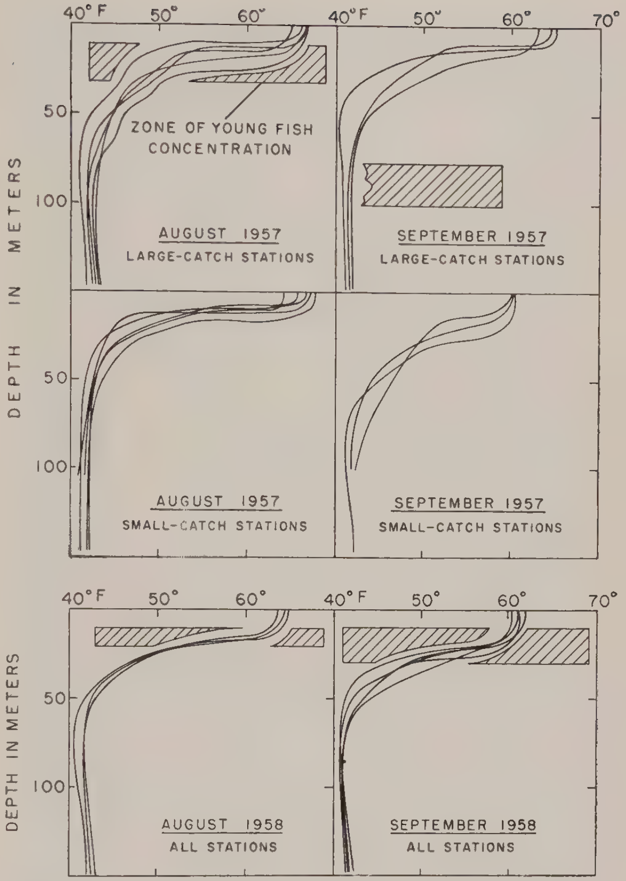

Figure 2. Water temperature profiles recorded at redfish midwater trawl stations in the Gulf of Maine in 1957 and 1958.

caught at night. With the exception of one large catch at 1100 hours in July–August, all of the largest catches of larvae at all depths were made during the night. This suggests that young fish are less available to the trawl during the day-time, perhaps being able to see it in time to escape.

The catch-per-tow of larvae collected on the four cruises is summarized in Table 5, arranged by the quarter of the day when caught. In general, the results show a higher percentage of night-time tows containing redfish, and a higher average catch-per-tow at night than in the day-time. The July–August 1958 data are not consistent with the rest, but these contain the least number of redfish and are therefore less conclusive than the other data. It appears that midwater trawling at night is many times more effective than day-time trawling, with the afternoon period being the least likely to produce large catches.

Day and night fishing was undertaken at several stations in an attempt to show a diurnal pattern of vertical movement by young fish. Despite this intensive effort, the tows that netted fish are too dispersed through the depths to show any clear pattern of diurnal vertical movement. In July–August 1957, the largest catches were consistently in the 10 to 30 m depths, day and night. In September 1957, the concentrations of small fish were at 80 to 110 m at night. The only suggestion of diurnal variation on both occasions was a slight vertical movement within the relatively narrow range of depths where the fish were concentrated at the time. There was no indication of diurnal movement of young fish between surface and deep water.

On two occasions in 1957 single large redfish were taken at mid-depth under circumstances suggesting either that they were living pelagically or were involved in a nocturnal vertical migration. Each was caught during early morning darkness, between 0230 and 0400 hours, a 29 cm female at 60 m depth in August and a 20 cm male at 100 m in September. The female was gravid with young about to be released and may have been rising in the water to release the young near the surface. Whatever the purpose, these occurrences at

Table 6

Summary of redfish length-frequencies by depth, July—August 1957 ("Albatross III"— Cruise Number 99)

Length (mm)	Depth in metres 10	20	30	40	60	100	Total
5	–	–	–	–	–	–	–
6	–	–	–	–	–	–	–
7	–	–	–	–	–	–	–
8	–	1	–	–	–	–	1
9	–	1	–	–	–	–	1
10	1	3	–	–	–	–	4
11	2	7	1	–	–	–	10
12	6	23	2	–	–	–	31
13	10	28	7	1	–	–	46
14	25	58	13	1	–	–	97
15	22	74	12	–	–	–	108
16	12	105	8	1	1	–	127
17	19	127	8	–	–	–	154
18	19	153	3	–	1	–	176
19	13	225	7	2	1	–	248
20	8	237	5	4	–	–	254
21	8	287	4	–	1	–	300
22	12	343	2	3	2	–	362
23	12	349	3	1	2	–	367
24	14	346	3	–	–	1	364
25	10	330	4	2	2	–	348
26	7	240	2	–	2	–	251
27	11	241	1	1	3	–	257
28	10	187	3	1	7	–	208
29	13	149	3	1	–	–	166
30	12	90	1	3	3	–	109
31	11	84	–	–	–	–	95
32	6	59	2	1	3	–	71
33	6	36	–	–	–	–	42
34	3	32	2	1	–	–	38
35	2	21	–	–	1	–	24
36	3	14	–	–	1	–	18
37	2	4	–	–	–	–	6
38	–	7	–	–	–	–	7
39	–	–	–	–	–	–	–
40	–	–	–	–	–	–	–
Total	279	3861	96	23	30	1	4290
Mean length (mm)	22·2	23·8	19·5	24·1	27·2	23·5	23·6

mid-depth support the hypothesis that movement off the bottom is the cause of a nocturnal decrease in availability of redfish in the Gulf of Maine.

Length composition

Redfish taken at the southern stations in July–August 1957 were considerably larger than those from northern stations. North of Cape Ann (Fig. 1) the fish were from 4 to 10 mm smaller and were fewer than at the stations to the south. This condition was altered somewhat in September 1957, and the larger fish were found more northerly along the eastern edge of the deep water. The numbers of larvae taken in the 1958 collections are not sufficient for a comparison of length composition.

The length composition by depth in 1957 indicates a slight trend toward larger fish in deep water. The size range from surface to bottom is surprisingly uniform both in July–August and September (Tables 6 and 7, Figure 3). Apart from individual differences between stations, the average lengths of larvae from each depth are within a few millimetres. In both months the smallest average length was observed at the 30 m depth. There is no apparent explanation for this.

In July–August 1958, the fish were concentrated in

Table 7

Summary of redfish length-frequencies by depth, September 1957 ("Albatross III" — Cruise Number 102)

Length (mm)	Depth in metres 10	20	30	40	60	80	100	110	Total
15	–	–	–	–	–	–	–	–	–
16	–	–	–	–	–	–	–	–	–
17	–	–	–	–	–	–	1	–	1
18	–	–	1	–	–	1	–	–	2
19	–	–	–	–	–	–	–	–	–
20	–	1	–	–	–	1	–	–	2
21	–	–	1	–	–	1	–	–	2
22	–	1	–	–	–	–	–	–	1
23	2	–	–	–	–	1	–	–	3
24	1	1	–	–	1	2	–	–	5
25	1	2	–	1	–	–	1	–	5
26	2	3	–	–	–	2	1	1	9
27	–	1	1	–	–	5	2	–	9
28	2	3	–	1	1	2	2	–	11
29	–	4	–	–	1	4	3	1	13
30	5	3	1	–	–	5	5	1	20
31	3	2	1	5	1	5	11	3	31
32	2	2	–	5	–	14	21	4	48
33	7	5	2	3	1	13	26	6	63
34	3	2	2	6	–	22	42	14	91
35	11	10	2	6	2	26	59	25	141
36	13	8	6	3	1	22	72	25	150
37	14	10	2	5	–	37	62	27	157
38	9	2	2	6	1	26	40	26	112
39	13	5	–	8	2	33	35	16	112
40	6	2	1	4	3	27	23	13	79
41	5	4	1	–	1	19	20	8	58
42	6	2	–	1	1	21	17	3	51
43	4	4	–	1	–	24	19	2	54
44	3	1	–	2	1	20	13	2	42
45	2	–	–	1	1	15	7	–	26
46	1	–	–	–	–	10	4	1	16
47	–	1	1	–	–	11	6	–	19
48	3	–	–	–	–	6	9	–	18
49	–	1	–	–	–	11	6	–	18
50	1	2	–	–	2	8	5	–	18
51	–	1	–	–	–	10	7	–	18
52	–	–	–	–	–	8	2	–	10
53	–	–	–	–	–	3	–	–	3
54	1	–	–	–	–	7	2	–	10
55	1	–	–	–	–	4	1	–	6
56	–	–	–	–	–	2	–	–	2
57	–	–	–	–	–	1	–	–	1
58	–	–	–	–	–	1	–	–	1
59	–	–	–	–	–	–	–	–	–
60	–	–	–	–	–	–	–	–	–
Total	121	83	24	58	20	430	524	178	1438
Mean length (mm)	37·7	36·0	34·9	36·6	38·4	40·5	38·2	37·4	38·5

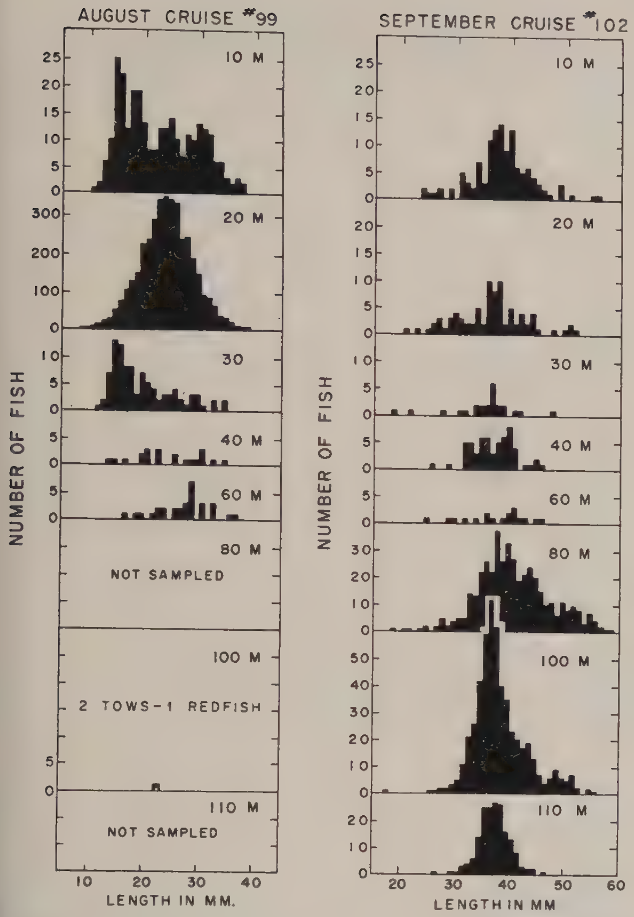

Figure 3. Length composition and depth distribution of young redfish taken by midwater trawl in 1957.

the upper strata, with equal numbers at 10 and 20 m (Table 8 and Figure 4). Size ranges at the two depths were similar. In September there was a gradual increase in average length associated with increased depth (Table 9 and Figure 4). The large numbers of small larvae at 10 m depth and the generally smaller average lengths at all depths can be attributed to the added stramin cod-end.

In comparing the length composition of the specimens collected during the two years, the similarity of the July–August data and the dissimilarity of the September collections are evident. The average lengths recorded in July–August of both years are nearly identical despite the tremendous difference in the number of fish collected (Tables 6 and 8). On the other hand, the September collections bear little resemblance to each other (Tables 7 and 9).

Growth of young fish

A high growth-rate during the pelagic period is indicated by the increase in average length of the young fish sampled between July–August and September 1957. An average increase in length of 14·9 mm in 42 days is much faster than the growth of the adult fish in the same area (Table 10). Average length increased at all depths, increases ranging between 11·2 and 15·5 mm at different depths. The consistency of the changes in length throughout this comparatively broad area suggests that this is a rather precise measure of the growth-rate of young redfish in the Gulf of Maine. The rapid growth agrees with the growth-rate of young-of-the-year redfish previously estimated from less complete data of the pelagic stages (Kelly and Wolf, 1959).

Starting about 25. June, the middle of the usual 4-month spawning period, a 5 mm larva growing at the rate of 14·9 mm per 42 days would attain an average length of 50 mm in 126 days, or by about 28. October. This growth agrees closely with the observed average length of the youngest age-group (pre-annulus) collected in fine-mesh bottom trawls in the Gulf of Maine in November of earlier years. Therefore, it appears that the Gulf of Maine fish are about 4½ months old when they reach a length of 50 mm and move to the bottom.

In reviewing the earlier studies of *Sebastes* cited above, it was noted that fragmentary records of larvae and postlarvae from widely separated areas in the North Atlantic are similar. The time of occurrence and size of specimens observed differed little regardless of where collected. These data are shown together in Figure 5 to compare the growth-rates of larvae throughout the area. The first part includes all data available from the Gulf of Maine. Data from the pertinent collections of Jensen (1922), Dannevig (1919), Frost (1938), and Tåning (1949) from other regions were combined in the second part of Figure 5 (Table 11).

The composite figure gives an almost continuous record of the pelagic growth during the summer and autumn months. A line fitted to the data leads directly to the sizes of fish sampled from the bottom in the Gulf of Maine in the late autumn and winter. Data from all areas fall close to the estimated average growth curve, suggesting that, with local variations, the larval growth-rate in the western North Atlantic is approximately the same.

Duration of pelagic stage

Evidence from the study of early growth indicates a probable average pelagic stage of 4½ months' duration. Assuming that the fry are capable of only local orientation movements, they could be transported great distances by surface water currents in that length of time. The relationship of redfish larvae to the hydrography of the Gulf of Maine and adjacent waters is not adequately understood to formulate a hypothetical

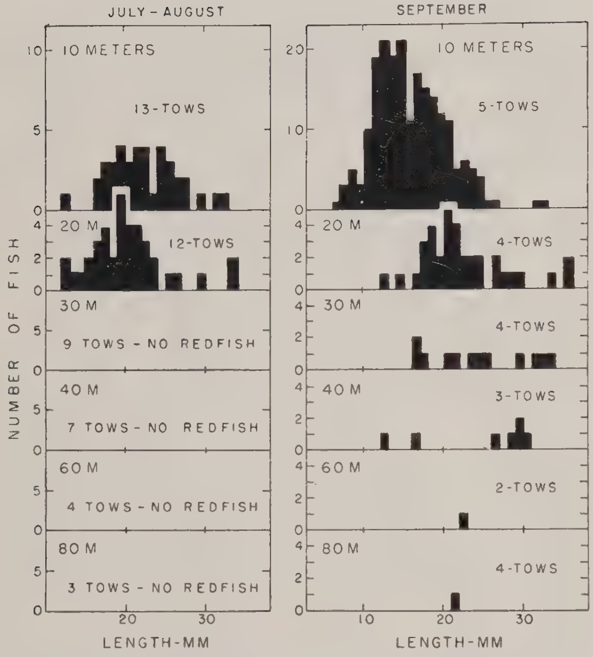

Figure 4. Length composition and depth distribution of young redfish taken by midwater trawl in 1958.

Table 8
Summary of redfish length-frequencies by depth, July—August 1958 ("Albatross III" — Cruise Number 116)

Length (mm) *	Depth in metres 10	20	Total
12	1	2	3
13	–	1	1
14	–	1	1
15	–	2	2
16	2	3	5
17	3	4	7
18	3	2	5
19	4	6	10
20	3	4	7
21	4	4	8
22	4	3	7
23	1	2	3
24	4	–	4
25	3	1	4
26	2	1	3
27	2	–	2
28	–	–	–
29	1	1	2
30	–	–	–
31	1	–	1
32	1	–	1
33	–	2	2
Total	39	39	78
Mean length (mm)	22·3	20·2	21·2

* No observations for 5–11 mm lengths.

Table 9
Summary of redfish length-frequencies by depth, September 1958 ("Albatross III" — Cruise Number 117)

Length (mm)	Depth in metres 10	20	30	40	60	80	Total
5	–	–	–	–	–	–	–
6	1	–	–	–	–	–	1
7	3	–	–	–	–	–	3
8	5	–	–	–	–	–	5
9	3	–	–	–	–	–	3
10	10	–	–	–	–	–	10
11	19	–	–	–	–	–	19
12	21	1	–	1	–	–	23
13	19	–	–	–	–	–	19
14	21	1	–	–	–	–	22
15	11	–	–	–	–	–	11
16	17	1	2	1	–	–	21
17	15	3	1	–	–	–	19
18	14	4	–	–	–	–	18
19	12	2	–	–	–	–	14
20	11	5	1	–	–	–	17
21	5	4	1	–	–	1	11
22	6	2	–	–	1	–	9
23	5	2	1	–	–	–	8
24	4	2	1	–	–	–	7
25	1	–	1	–	–	–	2
26	1	2	–	1	–	–	4
27	–	1	–	–	–	–	1
28	–	1	–	1	–	–	2
29	–	1	1	2	–	–	4
30	–	–	–	1	–	–	1
31	1	–	1	–	–	–	2
32	1	–	1	–	–	–	2
33	–	1	1	–	–	–	2
34	–	–	–	–	–	–	–
35	–	2	–	–	–	–	2
Total	206	35	12	7	1	1	262
Mean length (mm)	15·8	22·3	24·4	24·8	22·5	21·5	17·3

Table 10
Increase in average length of young fish, by depth zone, between July—August and September 1957

Depth (m)	July–August (Cruise No. 99) mm	September (Cruise No. 102) mm	Average increase mm
10	22·2	37·7	15·5
20	23·8	36·0	12·2
30	19·5	34·9	15·4
40	24·1	36·6	12·5
60	27·2	38·4	11·2
80	–	40·5	–
100	23·5	38·2	14·7
110	–	37·4	–
Mean length	23·6	38·5	14·9

model of larval drift. The pattern of larval distribution in the present study suggests that the currents in the Gulf of Maine tend to concentrate large numbers of larvae over the deep water in the south and central parts of the Gulf. From what is known of the flow of

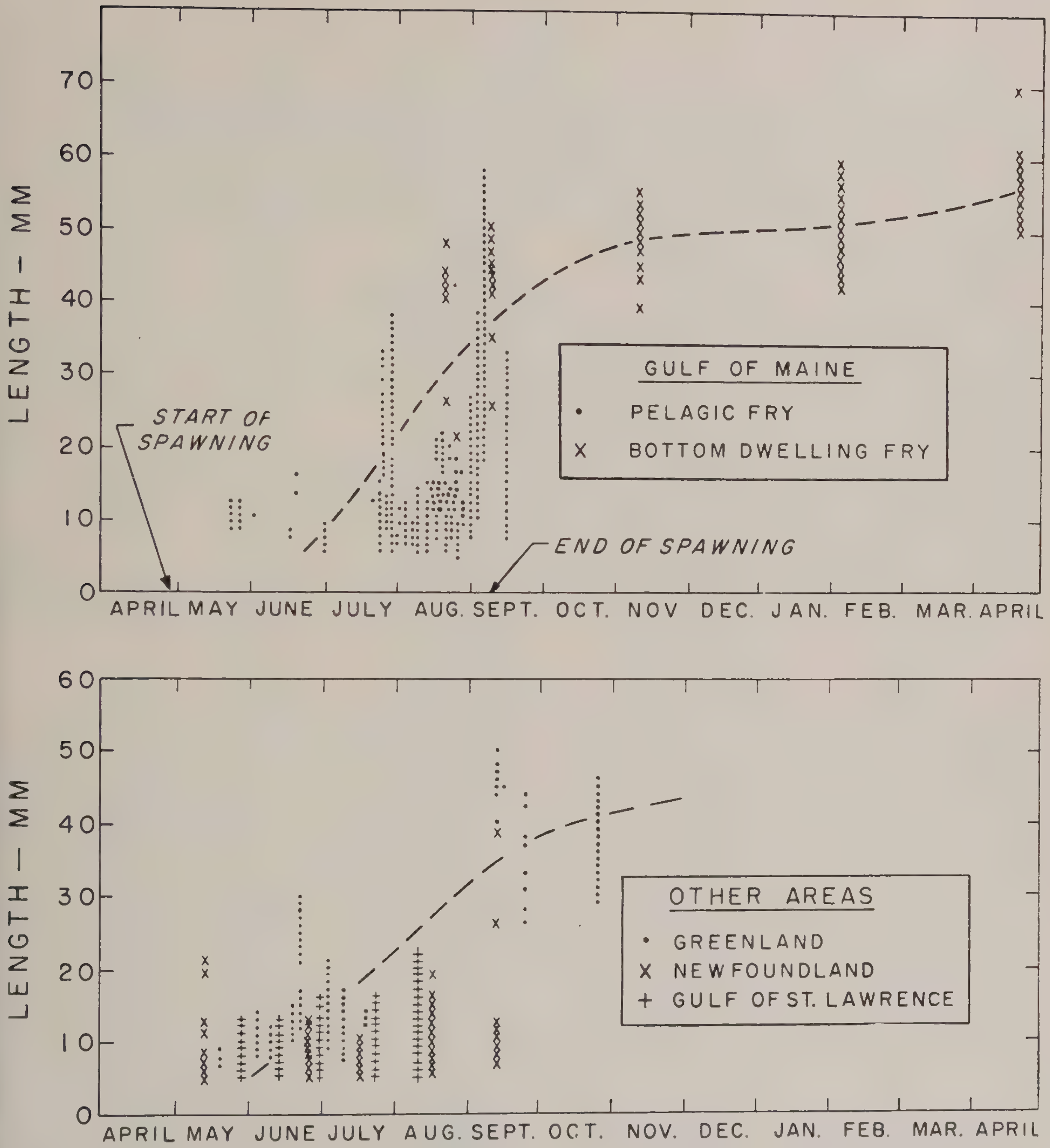

Figure 5. Approximate growth-rate of young redfish in the Gulf of Maine and other north-west Atlantic Ocean areas.

he Nova Scotian shelf water, it is likely that some *Sebastes* larvae originating from the populations on Nova Scotian banks are transported into the Gulf of Maine by the westerly currents around Cape Sable. Specific studies in this area will be necessary to establish his hypothesis.

Assuming the same duration of the pelagic stage in the Iceland–Greenland area, Jensen's theory of long-distance larval transport becomes very plausible. There is ample time for water currents of 3–4 miles per day to carry larvae as much as 500 miles from the location of spawning.

Table 11

Summary of north-west Atlantic larval and postlarval redfish collections pertinent to the study of growth-rate of young fish during the pelagic stage. Source of the data is indicated, with the date of collection, location, size range and number of specimens collected

(Length-frequencies from these collections are used in Figure 5)

Date of collection		Source	Location	Size range (mm)	Number of specimens
1895	18. July	Jensen (1922)	61°44′N–30°29′W	12–14	8
1896	1. June	Jensen (1922)	62°40′N–19°05′W	8·5–14	5
	3. June	Jensen (1922)	62°06′N–22°30′W	7·5–12	9
	12. June	Jensen (1922)	60°30′N–26°54′W	10–15	5
	13. June	Jensen (1922)	60°23′N–27°25′W	12–17	7
1908	14.–26. May	Jensen (1922)	58°59′N–30°50′W to 58°08′N–39°12′W	7–9	Several hundred
1909	25. Sept.	Jensen (1922)	60°05′N–46°35′W	27·5–43·0	9
1912	July	Bigelow (1914)	Gulf of Maine	6–12	314
	August	Bigelow (1914)	Gulf of Maine	5–21	467
1913	June	Jensen (1922)	East coast Greenland	22–30	Great numbers
	24. Oct.	Jensen (1922)	65°40′N	29–45	Some
1914	July	Bigelow (1917)	Gulf of Maine	6–13	281
	August	Bigelow (1917)	Gulf of Maine	7–22	176
1914	29. May–4. June	Dannevig (1919)	Gulf of St. Lawrence	5–13	66
	9.–15. June	Dannevig (1919)	Gulf of St. Lawrence	5–13	108
	21.–29. July	Dannevig (1919)	Gulf of St. Lawrence	5–16	228
	3.–12. August	Dannevig (1919)	Gulf of St. Lawrence	5–22	220
	1. June–18. Aug.	Dannevig (1919)	Gulf of St. Lawrence	5–15	337
1915	May	Bigelow (1917)	Gulf of Maine	10	1
	June	Bigelow (1917)	Gulf of Maine	7–8	2
	August	Bigelow (1917)	Gulf of Maine	6–27	Many
	Sept.	Bigelow (1917)	Gulf of Maine	10–40	Swarm
1915	Sept.	Jensen (1922)	West Greenland	38–49	7
1925	June	Jensen (1926)	West Greenland	7–13	100+
	July	Jensen (1926)	West Greenland	7–17	100+
1931	May	Kelly and Wolf (1959) (Albatross II Coll.)	Gulf of Maine	8–12	13
	June–July	Kelly and Wolf (1959) (Albatross II Coll.)	Gulf of Maine	5–16	84
1932	July	Kelly and Wolf (1959) (Atlantis Coll.)	Gulf of Maine	5–18	2,234
1932–	May	Frost (1938)	Newfoundland area	5–21	40
1935	June	Frost (1938)	Newfoundland area	5–13	249
	July	Frost (1938)	Newfoundland area	5–10	117
	August	Frost (1938)	Newfoundland area	6–19	207
	Sept.	Frost (1938)	Newfoundland area	6–37	13
1947	29. June	Tåning (1949)	56°02′N–38°43′W	9–21	1,072
1953	August	Kelly and Wolf (1959)	Gulf of Maine	26–48	10
	Sept.	Kelly and Wolf (1959)	Gulf of Maine	25–50	17
	Nov.	Kelly and Wolf (1959)	Gulf of Maine	38–54	26
1954	Feb.	Kelly and Wolf (1959)	Gulf of Maine	42–59	83
	April	Kelly and Wolf (1959)	Gulf of Maine	50–67	25
	August	Kelly and Wolf (1959)	Gulf of Maine	5–15	216
1955	August	Kelly and Wolf (1959)	Gulf of Maine	4–21	97
1957	26. July–1. Aug.	(Present Study)	Gulf of Maine	8–38	4,290
	5.–9. Sept.	(Present Study)	Gulf of Maine	17–58	1,438
1958	28. July–1. Aug.	(Present Study)	Gulf of Maine	12–33	78
	14.–15. Sept.	(Present Study)	Gulf of Maine	6–35	262

Summary

Although the depth at which Gulf of Maine redfish larvae are released is not known, the newly spawned larvae (5 to 6 mm) appear at the surface and are concentrated in the upper 10 metres. As they grow to 10–15 mm the larvae move deeper to about 20 m depth where they remain until reaching a length of 25 mm. During this period they stay in the thermocline. When the fish exceed 25 mm they move deeper into the cold water below the thermocline. The movement from the cold middle waters to the bottom is probably influenced by the requirements of individual fish, some going to the bottom when only 25 mm while others 55 to 60 mm in length remain in midwater. Some large postlarvae are found on the bottom as early as August, while others appear to remain in midwater until October.

The relatively long pelagic stage is a period of rapid growth for redfish larvae. The average length attained by the time they move to the bottom appears to be between 40 and 50 mm. This length is reached in 4 or 5 months.

The pelagic period is long enough to permit the fry to drift long distances in the water currents. It is likely that the counterclockwise currents in the Gulf of Maine serve to concentrate the larvae in certain parts of the central area. However, in other less restricted areas, strong surface currents could transport the larvae for distances of several hundred miles.

There is little evidence of diurnal vertical movements of the planktonic larvae. The only obvious diurnal variation is the change in catchability of the larvae at all depths. This suggests that the fish can detect the trawl visually and escape from it during the daylight hours, but are less able to do this at night. The effect could be the reverse if taken in a different view. Perhaps the luminous planktonic animals are stimulated to flare with the approach of the trawl at night, thus attracting the fish toward a source of food and into the path of the net. Despite these variations in availability of the fish, the Isaacs-Kidd midwater trawl is an effective gear for sampling pelagic young redfish.

Great variations in redfish year-class strength undoubtedly occur. Midwater sampling indicates that the 1957 year-class was large and the 1958 class was very small in the southern Gulf of Maine. Several more years of sampling are necessary to determine the normal relative abundance of young-of-the-year redfish in mid-depths.

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10.

Larval and Postlarval Stages of *Sebastes* Species and *Helicolenus dactylopterus*

By

Å. VEDEL TÅNING †

(With Introductory Notes by E. BERTELSEN)

During his investigations in Faroe–Icelandic and Greenland waters in the 1920's and 1930's Dr. Tåning observed that the fry of *Sebastes* could be divided into two types according to the presence or absence of a distinct caudal pigment spot, consisting of one or a few melanophores.

According to the distribution of the two types he assumed that the fry with caudal spot belonged to *Sebastes viviparus* and the others to the, at that time, only other recognized species of *Sebastes* in these waters, *Sebastes marinus.*

He soon confirmed the first assumption through examination of larvae extruded from ripe *Sebastes viviparus* females, which are common in Faroese and Icelandic waters. *Sebastes marinus* in this stage were more difficult to obtain, and it was not until 1938 that he succeeded in obtaining ripe females of this species (one from Faroes and some from Iceland). He found that all the unborn larvae examined from these specimens lacked caudal melanophores. The series of development stages in Figures 1–3 were drawn by the artist Poul H. Winther under the direction of Dr. Tåning. The drawings were made in 1944 except for the figure of the unborn *S. viviparus* larva, which dates back to 1937, and the corresponding stage of *"S. marinus"* which was drawn in 1948.

Tåning drew attention to these observations at several scientific meetings and through other personal communications, and the pigment character has since been regularly used in the separation of different types of *Sebastes* larvae found in the eastern North Atlantic. However, publication of the drawings and descriptions was delayed by the uncertainty concerning the number of *Sebastes* species present in the North Atlantic, and by the fact that in 1947 Tåning found *Sebastes* fry with a caudal pigment spot in the western North Atlantic. Furthermore Tåning found single oceanic specimens with caudal pigment, mainly in the area between the Faroes and Reykjanes Ridge. They were too young (6–12 mm) to have been carried by currents from the coastal banks to the positions in which they were caught, and Tåning considered the three following possibilities:– that they were either (1) variants of *S. marinus,* or (2) derived from interbreeding with "the American form" or (3) were the larvae of oceanic living *S. viviparus.*

Although it is now known that caudal pigment spots are found in larvae of *Sebastes* species other than *S. viviparus,* and although there are no means of separating larvae of *S. marinus* from, for instance, *S. mentella,* it is felt that Tåning's figures and notes are most useful to the further study of these problems and should be published.

The accompanying descriptive notes are fragments of an unfinished manuscript by Dr. Tåning. In these and the descriptions of the figures the specific names have been retained as in Tåning's original notes, i.e. *viviparus* and *marinus.* As no intermingling with other *Sebastes* species with caudal pigment spot is likely in the area where the *S. viviparus* were collected, the identification is no doubt correct, but whether the series of *"S. marinus"* fry may contain specimens of *S. mentella* is uncertain.

The series of developmental stages of *Helicolenus dactylopterus* is not commented on in the notes and manuscripts left by Tåning. Being the only species of its genus in the North Sea and eastern North Atlantic, where the specimens were collected, the identification does not need verification. The most significant feature in the pigment pattern seems to be the three melanophores seen ventrally on the caudal peduncle, well in front of the base of the caudal fin. The figures are sufficiently self-explanatory to be published without further comments.

E. Bertelsen

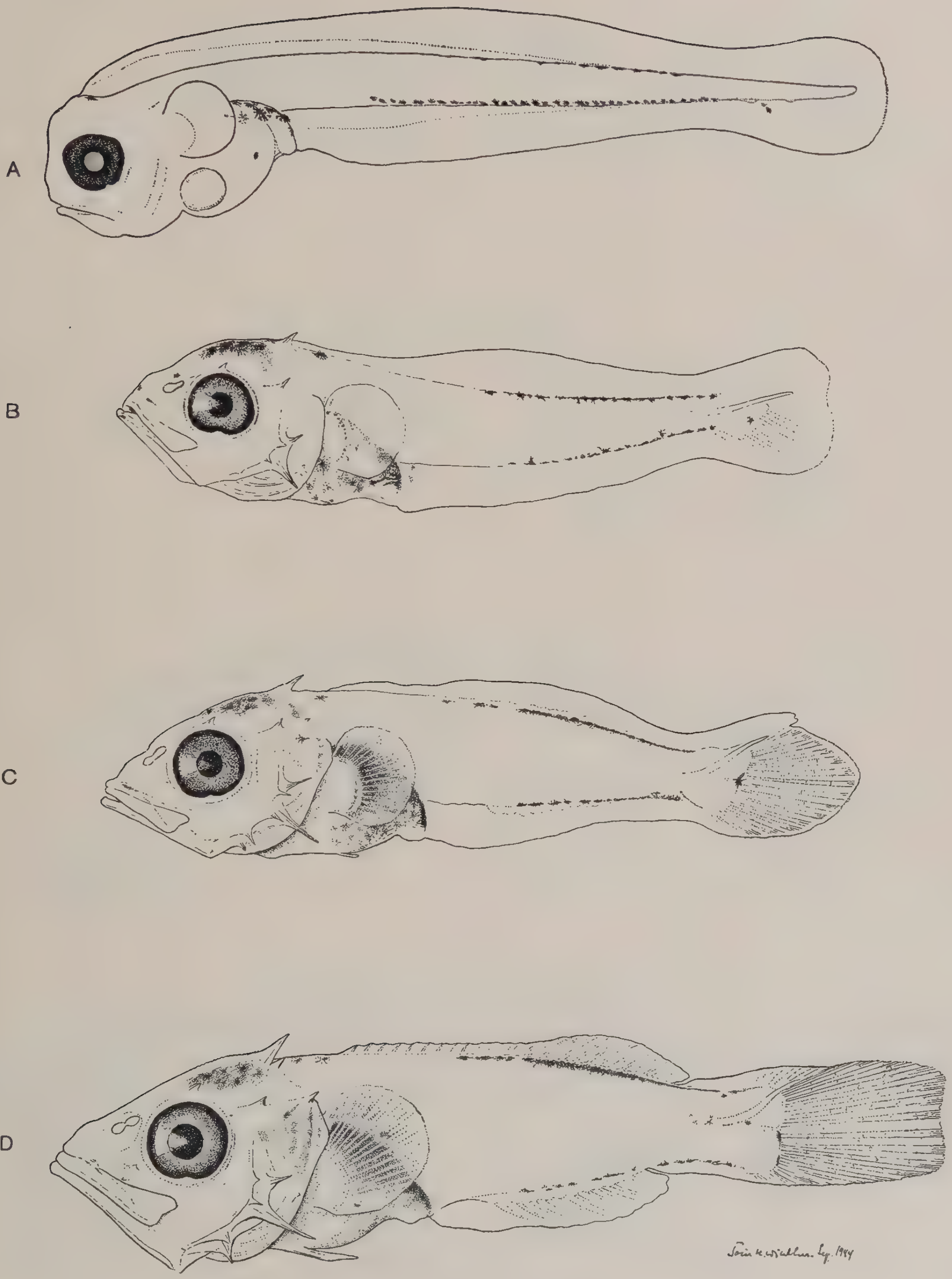

Figure 1. *Sebastes viviparus.*

A. 5·8 mm, from ovary of *S. viviparus* from Iceland 26/6 1909.
B–D. "Dana" st. 5288 (62°00'N, 6°12'W), sonic depth: 122 m, stramin net, 65 m.w., 11/7 1934.
B = 8·9 mm, C = 10·1 mm, D = 13·5 mm.

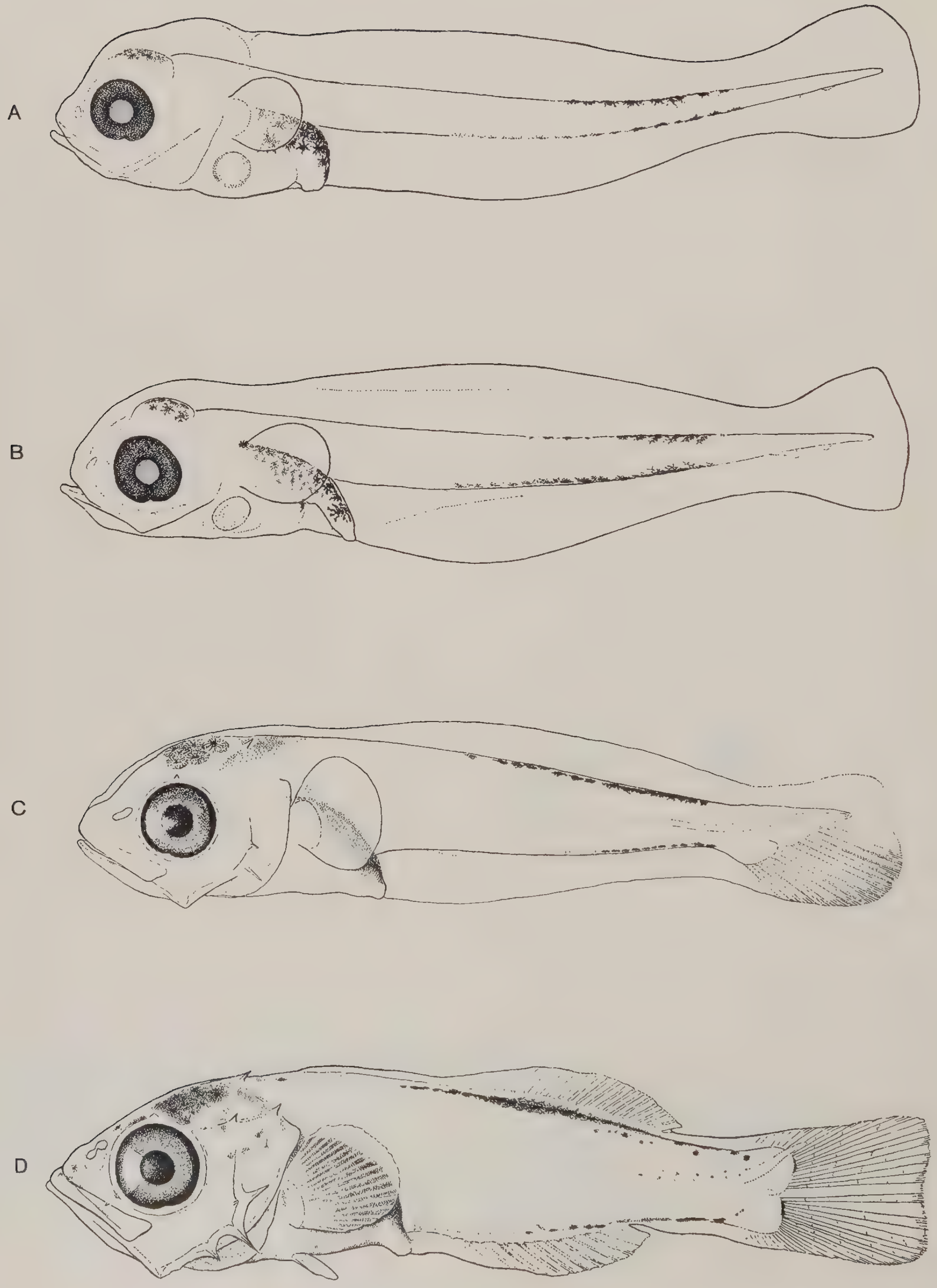

Figure 2a. *Sebastes marinus.*

A. 6·8 mm, from ovary of *S. marinus,* 44 cm. "Dana" st. 6691 (51°00′N, 44°20′W, West Greenland), shrimp trawl, 260 m.w., 27/6 1947.
B. 7·4 mm, "Dana" st. 5083 (62°45′N, 16°01′W), stramin net, 500 m.w., sonic depth: 1975 m, 7/5 1934.
C. 10·5 mm, "Dana" st. 2307 (60°20′N, 29°21′W), stramin net, 1500 m.w., 30/5 1925.
D. 15·7 mm, "Dana" st. 4438 (64°13′N,38°15′W), sonic depth: 450–470 m, stramin net, 15 m.w., 11/7 1932.

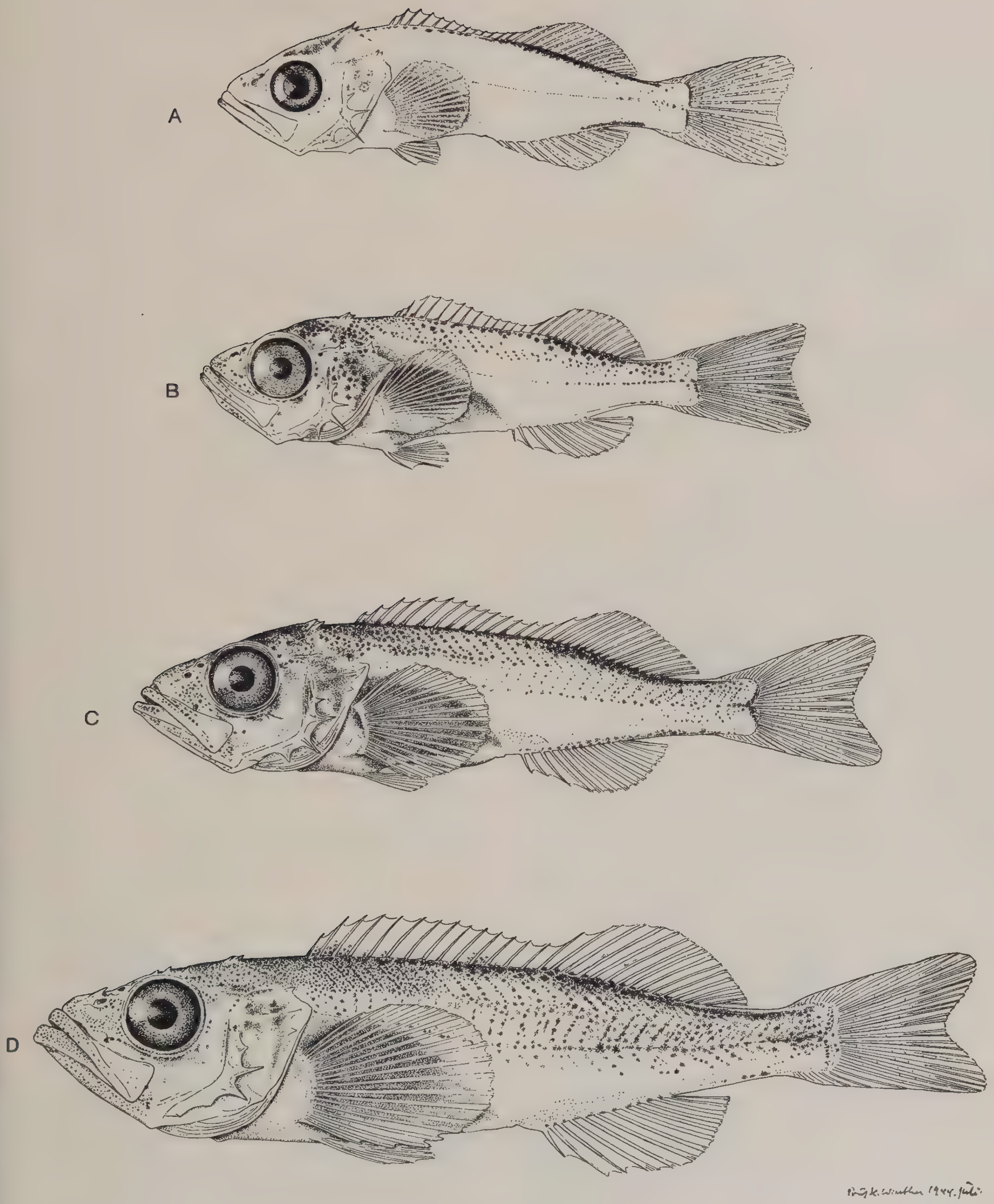

Figure 2b. *Sebastes marinus.*

A. 20·9 mm, "Dana" st. 4227^{III} (64°45′N, 36°30′W), sonic depth: 325 m, stramin net, 15 m.w., 17/7 1931.
B. 27·0 mm, "Dana" st. 4681 (60°19′N, 42°11′W), stramin net, 15 m.w., 14/8 1933.
C. 34·5 mm, "Dana" st. 4682 (60°00′N, 42°25′W), sonic depth: 295 m, stramin net, 65 m.w., 14/8 1933.
D. 52·0 mm, "Dana" st. 4681 (60°19′N, 42°11′W), stramin net, 15 m.w., 14/8 1933.

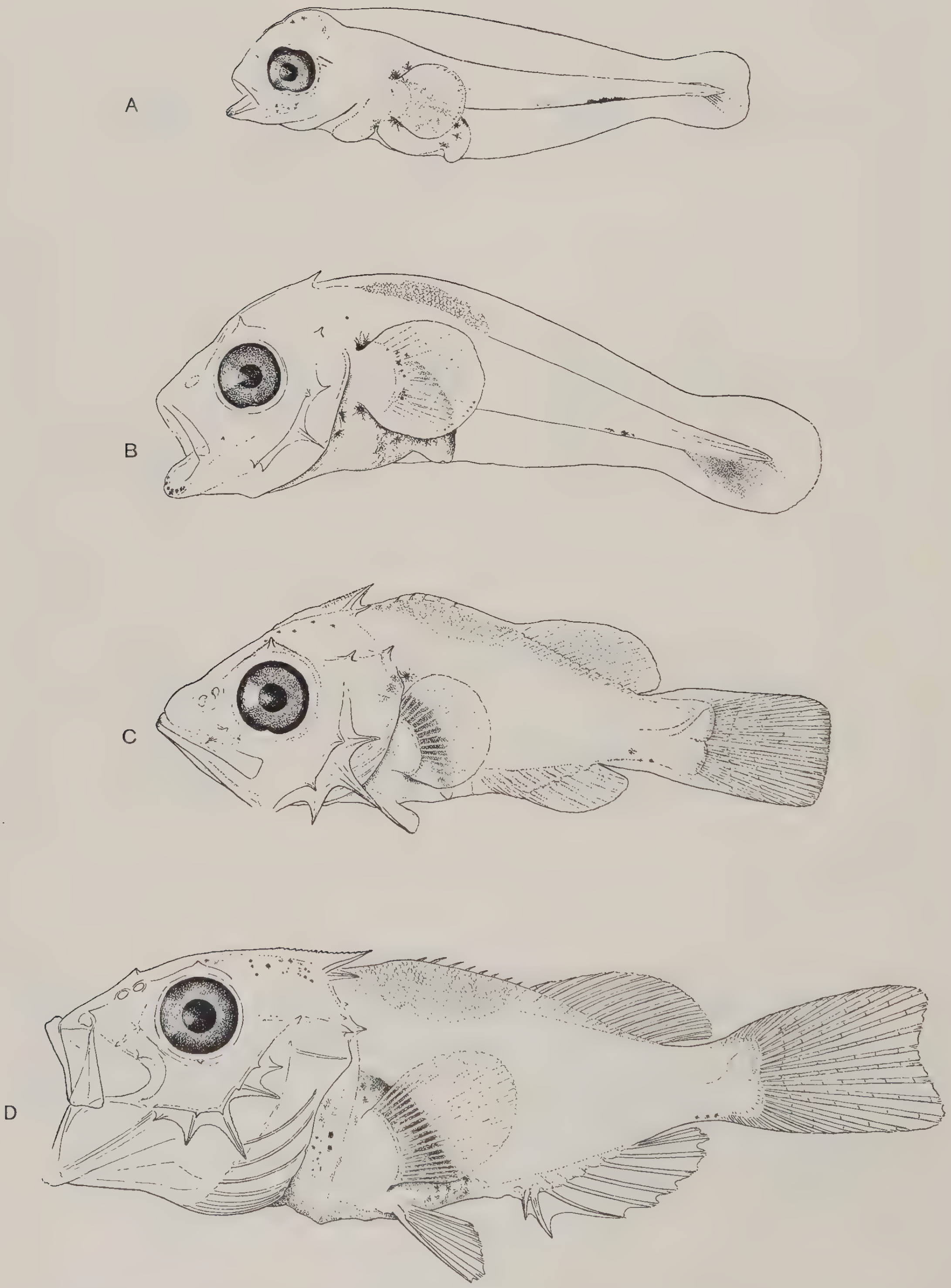

Figure 3. *Helicolenus dactylopterus.*

A–B. "Thor" st. 21 (58°28′N, 12°13′W), sonic depth: 1200 m, young-fish trawl, 65 m.w., 31/5 1908. A = 3·6 mm; B = 5·6 mm.

C. 10·0 mm, "Dana" st. 6094 (61°08′N, 2°10′W), sonic depth: 515 m, stramin net, 100 m.w., 14/7 1939.

D. 19·0 mm, "Dana" st. 5899 (52°38′N, 15°13′W), sonic depth: 1188 m, stramin net, 50 m.w., 21/6 1938.

A. On the Identification of the Young Stages of *Sebastes marinus* L. and *Sebastes viviparus* Kr.

Identification of *Sebastes viviparus*

Just before hatching the eggs of *Sebastes viviparus* are somewhat oblong, about 2·0 × 1·25 mm. The total length of the unborn larvae is generally slightly below 6 mm. A large oil globule is still present. It is of a strong yellow-green colour of greater intensity than in *S. marinus.* Vitellum, head, and the region above the abdomen are faintly yellow. No other distinct melanophores than those described below are seen. The eyes are pigmented, blue and iridescent. When extruded from the female the mass of fry (and unhatched eggs) is of more intense yellow-green colour than in *S. marinus.*

There is a single or a small number of melanophores on the dorsal side of the head, several above the intestine and abdomen, and one or a few on its side. Furthermore there is a dorsal and ventral series of melanophores along the body. The dorsal series consists of fewer (about 10) and, especially anteriorly, more scattered melanophores than the ventral, in which there are often 2–3 per each myotome. The ventral eries may reach forward to about 1½ eye-diameters behind the intestine. Posteriorly this series reaches to a point somewhat in front of the place where, later on, he notochord turns upwards. The position and number of the dorsal and ventral melanophores may vary quite onsiderably.

Finally, below the notochord, there is a distinct melanophore extending onto the embryonic fin, just t the place where the first faint traces of the devel- ping caudal rays can be observed. This melanophore characteristic of *S. viviparus* and is absent from *S. marinus* larvae of the same stage.

After birth some time elapses before other melano- hores develop, outside the groups mentioned above. Of these those on the head and abdomen, especially, ncrease in number and intensity. Then, when the larvae reach a total length of 10–14 mm, pigment starts to develop at the base of the caudal fin, and soon covers the characteristic primary caudal melanophore. At a similar length, medio-lateral pigment starts to develop on the caudal peduncle and pigmentation begins at several places on head and body; also, the silvery colour of the abdomen, which may be seen faintly in specimens of 9 mm, spreads and becomes more distinct.

By the time when a length of about 15 mm is reached, some erythrophores may be found at the base of the caudal fin. These are the only colour-chromatophores behind the anus which have, so far, been observed in larvae of this species.

Identification of *Sebastes marinus*

Embryos of *S. marinus* near the stage when they are born, are very similar to those of *S. viviparus,* but according to the material examined, are somewhat longer (mostly more than 6 mm), corresponding to the somewhat larger egg-size (2·3 × 1·6 mm just before hatching). The oil globule is pale yellow (not intense yellow-green as in *S. viviparus*) and the yellowish tint on head and abdomen is very faint. Owing to this the mass of fry (and unhatched eggs) when extruded from the female, is of a paler colour than in *S. viviparus.*

The same groups of melanophores as in *S. viviparus* are found on head, intestine, and abdomen as well as dorsally and ventrally on the body, but melanophores are lacking below the end of the notochord at the place where the caudal fin later develops. However, in this species also, pigment develops at the base of the caudal fin when the larvae are about 10 mm or somewhat larger. For this reason it may not be possible to distinguish the larger larvae of the two species by means of this character.

B. Colour-Chromatophores in *Sebastes* Fry

Whereas chromatophores of any colour but black are bsent from most oceanic fish, weakly developed anthophores, and on rare occasions single erythro- hores are present in *Sebastes marinus.* In the coastal ecies *S. viviparus* (and *S. fasciatus*) both kinds of lour-chromatophores are much more numerous. The ason for this difference in oceanic and coastal-bank h is not known, but the phenomenon is very con- icuous and is also evident in the groups into which e genus *Sebastes* is divided.

The distribution of colour-chromatophores in *S. viviparus,* which is in this respect the best provided, will be described first.

On the dorsal side of the head some bright yellow (sometimes more yellowish-green) chromatophores are found between the melanophores; occasionally these xanthophores spread out so that they form a more diffuse pigment between and below the melanophores; this diffuse, yellow pigment is also found on the dorsal side of the anterior part of the body. It gives the larvae of *S. viviparus* a conspicuous yellow tinge which is almost absent from *S. marinus*. Between the black chromatophores, which are situated dorsally on the posterior part of the body and on the caudal peduncle, yellow chromatophores are also found extending nearly to the base of the caudal peduncle where the series of pigment cells stops. In cases where the foremost melanophores are absent from this group, yellow chromatophores may nevertheless be found there. Xanthophores are found less frequently amongst the ventral row of melanophores from the anus to the base of the caudal peduncle.

Finally, several colour-chromatophores are found, especially medio-laterally on the caudal peduncle and along the upward curved part of the notochord; they are small but quite conspicuous and are best seen on young individuals whose caudal peduncle is still oblique. These colour-chromatophores are rarely found more anteriorly on the base of the caudal peduncle than the 6th or 7th myotome (counting from the tail). A few scattered colour-chromatophores may be found dorsally or ventrally of the more pronounced mediolateral row. Whereas the most anterior colour-chromatophores are always of a vivid light yellow – as are those found dorsally and on the head – those situated posteriorly, along the upcurved end of the notochord, may shade off into orange and red. Further, a number of small erythrophores – most often 4 or 5 – are found at the base of the caudal fin rays. Noteworthy is the fact that the yellow chromatophores may spread mediolaterally on the base of the caudal peduncle between the myosepta and in this way become internal colour-chromatophores. It should be stressed that the majority of the colour-chromatophores mentioned are small and not as conspicuous as the melanophores. Furthermore, they disappear within 2–4 days in a solution (abt. 4 %) of formaldehyde.

In *Sebastes* fry the abdomen becomes silvery at an early stage and the stomach shows brown through the body, probably on account of its content of small crustaceans.

Turning to *Sebastes marinus* the description can be brief and is based on that given above for *S. viviparus*; the colour-chromatophores have mainly the same distribution but have a much fainter effect, since they are fewer and smaller.

A few yellow chromatophores are nearly always found between the melanophores on the head, but they are not so numerous that the colour can be dominant – as it is in *S. viviparus*. This is perhaps also in part due to the fact that the diffuse body-pigment is almost entirely lacking in *S. marinus*.

Xanthophores are seldom seen between the dorsal and ventral pigment rows of melanophores on the caudal part. When present they are most often found dorsally.

The medio-lateral xanthophores are almost absent from the base of the caudal peduncle; a few may be found medio-laterally and dorsally of the middle line but as a rule they are very inconspicuous (and may only be seen by microscope); the erythrophores on the base of the caudal fin are likewise nearly always absent, or only a single or a few very inconspicuous erythrophores are to be found.

The fewest colour-chromatophores are found on larvae of the purely oceanic species of *Sebastes marinus*.

A number of *Sebastes* larvae with caudal melanophores were caught in the western Atlantic, north of the Flemish Cap in 1947. They were, with regard to colour-chromatophores, very closely similar to *S. viviparus* fry and in this respect did not resemble *S. marinus*. Likewise this fry of the American variety resembled the fry of *S. viviparus* in possessing a melanophore on the cleft between the two large hypural plates. Dannevig (1919) and Bigelow and Welsh (1925) show on their figures (drawings) of *Sebastes* fry that the American variety has the above-mentioned characteristic melanophore. These things considered, the general characteristics of the fry group the American variety with *S. viviparus*; in certain other characteristics it is however very similar to *S. marinus*.

11.

Variations in Caudal Pigmentation in Late-Stage Pre-Extrusion Larvae from *marinus*- and *mentella*-Type Female Redfish from the Newfoundland Area*

By

WILFRED TEMPLEMAN and E. J. SANDEMAN
Fisheries Research Board of Canada Biological Station, St. John's Nfld.

Abstract

Late-stage pre-extrusion larvae have been examined rom 37 *marinus*-type and 44 *mentella*-type redfish, btained from three widely separated localities in the ewfoundland area. Examination of 120 larvae from ach fish has revealed that a difference exists between he two types, in the relative presence or absence of audal melanophores in their larvae. The caudal elanophores, when present, are situated near the base f the caudal fin and ventral to the vertebral column. audal melanophores were absent in only 2·3 % of the larvae from *mentella*-type parents, in contrast to the absence of caudal melanophores in 76·1 % of the larvae from *marinus*-type parents. When only those larvae having caudal melanophores are considered, larvae from *marinus*-type parents usually have but a single melanophore whereas those from *mentella*-type parents usually have two caudal melanophores.

This difference between larval samples provides evidence of the existence of a real genetic difference between *mentella* and *marinus* types of redfish in the Northwest Atlantic.

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* Complete paper in J. Fish. Res. Bd. Canada, *16* (6): 763–89, 1959.

12.

Investigations on Eggs and Larvae of Commercial Fishes in Norwegian Coastal and Offshore Waters in 1957—1958*

By

K. F. WIBORG
Institute of Marine Research, Bergen

Abstract

The distribution of redfish larvae in the waters of orthern Norway has been studied during May–June the years 1948–58. During this period, the mean umber of larvae below 1 m^2 of sea surface varied etween 3 and 39, with minima in 1950–52 and 1955, axima in 1948–49, 1953, and 1957.

The horizontal distribution of redfish larvae in the orwegian Sea in May–June 1958 was found to agree with that given by Russian workers (Baranenkova, *et al.*).

At the beginning of June 1958, redfish larvae taken in vertical hauls with an egg-net in the Norwegian Sea measured 7–13 mm, mean size 9·4 mm, those from catches with a high-speed net in the middle of the month 7–19 mm (mean 11·7 mm). Redfish taken with the high-speed net at the beginning of August 1955 measured 12–27 mm (mean 19·8 mm).

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* Published in full in Fisk. Skr., Ser. Havunders., *12* (7). 1960.

SECTION IV

SEX AND MATURITY

Sex and Maturity in Relation to Distribution and Migration

Discussion Leader: Dr. J. MAGNÚSSON

Three papers were reviewed and discussed during this session:–

Krefft, G. "A contribution to the reproductive biology of *Helicolenus dactylopterus* (De la Roche, 1809) with remarks on the evolution of the Sebastinae."

Sorokin, V. P. "The redfish, gametogenesis and migrations of the *Sebastes marinus* L. and *Sebastes mentella* Travin."

Magnússon, J. "The sex ratio of catches of redfish at different times and localities."

(i) Sex

Shoaling of redfish by sexes allowed migrational investigations to be carried out whilst tagging techniques could not, as yet, be employed in oceanic populations, although successful taggings had been carried out in the Gulf of Maine and West Greenland.

Of all areas under study, the Barents Sea appeared to offer the best understanding of the movements of females and fry away from the spawning grounds. Assuming a pelagic release of young, this movement conformed with what would be expected from a knowledge of the seasonal hydrography, although the mechanism of the females' return to the spawning region was not yet clear.

(ii) Maturity

It was agreed that the spring concentrations of mature pre-spawning female *S. mentella* were not known in the Greenland and Iceland regions. The absence of planktonic larvae with the 'tail spot', as described by Templeman and Sandeman, required further explanation. Their absence from the plankton of the Barents Sea also, where spawning areas of *S. mentella* are well known, emphasizes this need.

It appeared that the length of the extrusion period of redfish is very variable. Whether intermittent release of young occurs, and this might be considered from the behaviour of the closely related *Helicolenus dactylopterus* as described by Dr. Krefft, was not yet established.

In order to continue this work and improve our knowledge of redfish movements it is recommended that:–

(1) Any information concerning areas of pelagic redfish concentrations should be investigated, so that tagging of line or pelagic trawl caught fish may be attempted. In this connexion selected weather ships should be provided with tagging equipment.

(2) Examination of pre-extrusion larvae of *S. mentella* and *S. marinus* from all areas should take place in order to determine the spawning areas, and also to facilitate the identification of planktonic fry.

(3) Relative fishing mortality of the sexes should be investigated further.

1.

A Contribution to the Reproductive Biology of *Helicolenus dactylopterus* (De la Roche, 1809) with Remarks on the Evolution of the Sebastinae

By
GERHARD KREFFT
Hamburg

Abstract

Scientific knowledge concerning the mode of reproduction of Scorpaenid fishes is limited to only a few species. Even for these all the details are not known. There are, for instance, no observations of the copulation of any Scorpaenid fish, and it is not even known whether or not the oviparous genera and species do copulate.

Sebastes Cuvier, 1829, and *Sebastodes* Gill, 1861, are known to be viviparous, while some species of *Scorpaena* Linnaeus, 1758, extrude their spawn embedded in a gelatinous matrix floating on the surface.

In this paper the mode of reproduction in the genus *Helicolenus* Goode and Bean, 1895, is discussed. Here fertilization is internal and at least one species from the Indian Ocean has been proven to be viviparous (Graham, 1956). Information on the reproduction of *H. dactylopterus* found in the literature is both scanty and inconsistent. Williamson (1911) and Jenkins (1925) were inclined to suppose that the species might be viviparous, whereas Ehrenbaum (1905 and 1936), Holt (1899), Tåning (1949), Dieuzeide, Novella, and Roland (1955), and apparently Boutière (1958) thought of *Helicolenus* as being an oviparous fish. Sparta (1928 and 1941) too considered the species to be oviparous, while Nybelin (1942) and Andriiashev (1954) affirm that it is viviparous.

Recent findings on Lousy Bank, in May 1959, during a cruise of F.R.S. "Anton Dohrn" raised the possibility hat there may be intraspecific differences in the mode of reproduction, dependent on environmental or geographic factors.

The ripe and immature intraovarian eggs of the species are enveloped in a thick gelatinous matrix. Those examined were clear and were found to be in an advanced blastoderm stage and to contain an oil globule. Beneath the jelly-like layer the ovary contained eggs of a much smaller size and in four different stages of development.

With respect to the reproductive characters *Helicolenus* appears to be intermediate between *Scorpaena* and *Sebastes* as, similarly, is its morphology. It certainly holds a position at the root of the ancestral line of the Sebastinae and is best understood as a link between that viviparous subfamily and the oviparous Scorpaeninae.

There are seven species and subspecies of the genus described to date. They all are so closely related to each other that they may represent a single polytypic, allopatric "Rassenkreis". The distribution of the different forms shows two chains running around the globe in a bipolar, antitropic sense. This type of distribution also links the two subfamilies closely together, but there is a gap in the East Pacific. The preference for deep water may have been advantageous for the wide distribution of the genus. At the same time the bathymetric adaptation may have resulted in the ability to reproduce viviparously, and so points, possibly, to the manner of evolution of the Sebastinae.

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2.

The Redfish; Gametogenesis and Migrations of the *Sebastes marinus* (L.) and *Sebastes mentella* Travin

By

V. P. SOROKIN

PINRO, Murmansk, U.S.S.R.

The redfish *Sebastes marinus* (L.) and *Sebastes mentella* Travin, are of great importance to the trawl fishery by their abundance and the size of concentrations they form. It is therefore easy to understand why so great and so fully justified an interest in the behaviour of this fish has developed.

Within recent years a significant part of the life history of the redfish, inhabiting the Barents Sea and the Norwegian Sea, has been the subject of study. Age and rate of growth have been studied by N. P. Smaragdova (1936), V. V. Veshchezerov (1941), A. Kotthaus (1952), and E. I. Surkova (1957). Its distribution and its fisheries have been investigated by V. V. Veshchezerov (1941), N. A. Maslov (1944), V. I. Travin (1949, 1951, and 1957), and A. S. Baranenkova (1957). G. V. Boldovski (1944) reported on the redfish feeding behaviour.

V. F. Schmitt (1944) studied the development of the ovaries, embryonic development of the eggs, and the larval distribution after "spawning". Similar studies have been carried out by K. H. Lüling (1951), who did not seem to know about the work of Russian investigators (Schmitt and others), concerned with the life history of the redfish, as is seen from this quotation from the introduction to his paper: "We may say that we know almost nothing about the reproductive biology of the redfish *Sebastes marinus.*" Dr. J. Magnússon (1955) and Sorokin (1956) made histological gametogenesis studies independently of each other.

The present paper is not aimed at a critical analysis of all the data on the biology of the redfish. However, it was thought useful to try to assess how far the migrations of redfish in the Barents and Norwegian Seas are inter-related with the processes going on in the gonads.

The distribution and migration areas of *S. marinus*, as described by N. A. Maslov (1944), still remain valid (see Fig. 1). Recent investigations have only completed and defined this general scheme.

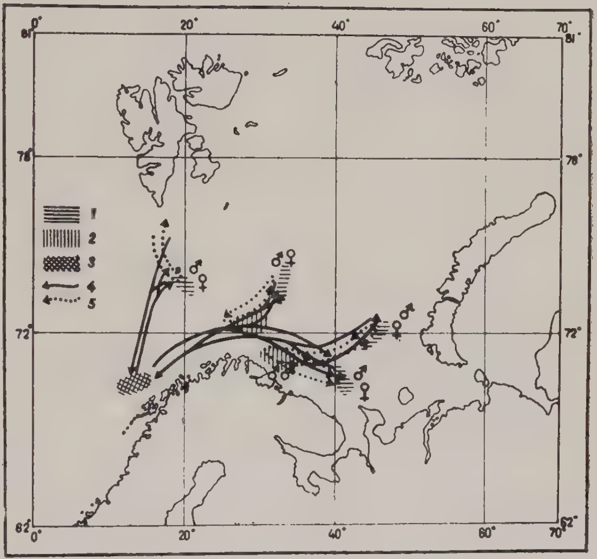

Figure 1. Diagram of *S.marinus* (L.) migrations according to N. A. Maslov.

1 = "spawning" areas
2 = areas of autumn/winter concentrations of males and females
3 = areas of spring concentrations of males
4 = migrations of females
5 = migrations of males

In the Barents and Norwegian Seas, to the east of the continental slope, *S. marinus* females liberate their larvae in the Lofoten Islands area and along the slope further north, as far as approximately 71°N. Liberation of larvae starts in the second half of April. It is at its height in May and comes to an end in the first half of June.

The spent *S. marinus* females migrate to the feeding grounds. At least three such areas are known: the eastern Barents Sea as far as Goose Bank (Travin reports *S. marinus* being caught incidentally at 73°N, 50°E); the Demidov Bank (Norwegian fishermen call it "Thor Iversen Banken") and adjacent northern and eastern areas; the third area includes the slopes of the Bear Island Bank and the continental slope of West Spitsbergen. *S. marinus* is sometimes found north-east of Hope Island (78°N; Travin, 1949).

After liberation of the larvae, the ovaries become reduced in size and weight (maturity factor — 0·2–1·1 %),* and become flabby; the membrane is shrunken. Cut sections show connective tissues of the follicular membranes to be partly degenerate. Sometimes unfertilized eggs in the process of resorption occur in the ovaries. The stroma of such an ovary contains sex cells of several generations, beginning with oogonia and including oocytes with a follicle of one or two layers. In June certain females have oocytes in the ovaries, with yolk accumulating in the plasma. Yolk deposition in the oocytes of older generations is not simultaneous, i.e. the vitellogenesis is of an asynchronous nature.

Vitellogenesis does not appear to be very active during June, July, and August, and the m.f. does not show a significant rise (1·2 % on average); by August it increases to 1·8 %. The diameter of the older generations of oocytes varies from 200 to 300 μ during this period.

The shoals of males and females, formerly separated, unite during these three months of the feeding migration, and *S. marinus* disperses on the feeding grounds mentioned above.

Cut sections of ovaries suggest that in September vitellogenesis becomes more active; the yolk granules increase in size (12–19 μ), as also does the ovary-mass. M.f. averages 2·3 % and in some cases even reaches 2·6 %. During November/December *S. marinus* leaves the feeding grounds, this being concurrent with and probably due to the beginning of winter cooling of the water.

Yolk accumulation is completed in January–February, sometimes in March. The oocyte is filled with large yolk granules; the nucleus loses its round form and becomes amoebiform; the nucleoli disappear and zona radiata begin to form. Diameter of such (living) oocytes varies from 900 to 1100 μ. The follicular membrane is stretched and epithelial cells are stretched out and flattened. The ovaries increase more in size and become heavier; the membrane stretches and becomes thin and transparent, so that oocytes can easily be seen through it. M.f. increases to 4–6 %, whilst some females have been found to possess a m.f. of 10·2 %; such fish occur from Murman Bank to Finnmark Bank; in the Norwegian Deep; in the Demidov Bank and Bear Island Bank areas.

Later on, when the albumen components of the oocyte have taken up water, homogenization begins and the oocyte becomes transparent. Meiosis takes place, followed by ovulation and fertilization (gametic syngamy). The diameter of the oocyte in the ripe condition attains 1500 μ. The ovaries are of a greenish-gray colour. The eggs lie free in the ovary-cavity and, if the belly of the female is lightly pressed, are discharged from the oviducts. The ovaries grow larger still and occupy more than half of the body cavity. M.f. averages 7 %, some specimens attaining a m.f. of 12 %.

Females bearing ripe (and fertilized) eggs are found in February and March on the Finnmark Bank and westwards, in the Kopytov area, and in the Western Deep. Females with eggs already fertilized are rarely found east of the Kola meridian or on the slopes of the Bear Island Bank. The author, at least, has never had an occasion to observe them.

Egg ripening and fertilization are followed by an active migration of females to the "spawning" places. This is also the period of formation of unisexual shoals.

After fertilization the period of embryonic development begins, also characterized by an increase in the size of the eggs and of the ovary as a whole. The eggs' spherical form changes into an elliptical one. That is why V. F. Schmitt adopted the value of half the sum of diameters for characterizing the eggs' growth. The largest egg size so measured (in fixed material) varied from 1980 to 2150 μ.

As the eggs tend to be discharged from the ovaries when they have reached the embryonic stage, the weight of the ovaries cannot be determined exactly. Despite this fact ovaries were weighed and it was found that the mean m.f. of the great majority of specimens was not lower than 11·3 %. Figure 2 shows the variation of the m.f. of *S. marinus* during the year.

Here a reservation must be made, in that observations from this material do not agree with Lüling's opinion, that copulation would affect the growth-rate of oocytes.

Observations make it possible to suggest that the copulation period does not affect the rate of vitellogenesis and the period of fertilization of the oocytes. In the case of some females which remain unfertilized, vitellogenesis is not hampered and ovulation takes place in the normal way. Unfertilized oocytes become degenerate or, eventually, abortive spawning takes place. Females with ripe but unfertilized oocytes have been found relatively often, but this problem will be discussed elsewhere.

At the time when the females start liberating larvae, active spermatogenesis is observed in the testes of the males. In April numerous cells in the testes of most of the males are observed in the process of division, at the metaphase or prophase of primary meiosis. Spermatids are already present in almost 50 % of the spermatocysts, being especially numerous in the gonads of males

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* The gonad weight, relative to the total weight of the fish, expressed in % is called the "maturity factor" or briefly m.f.

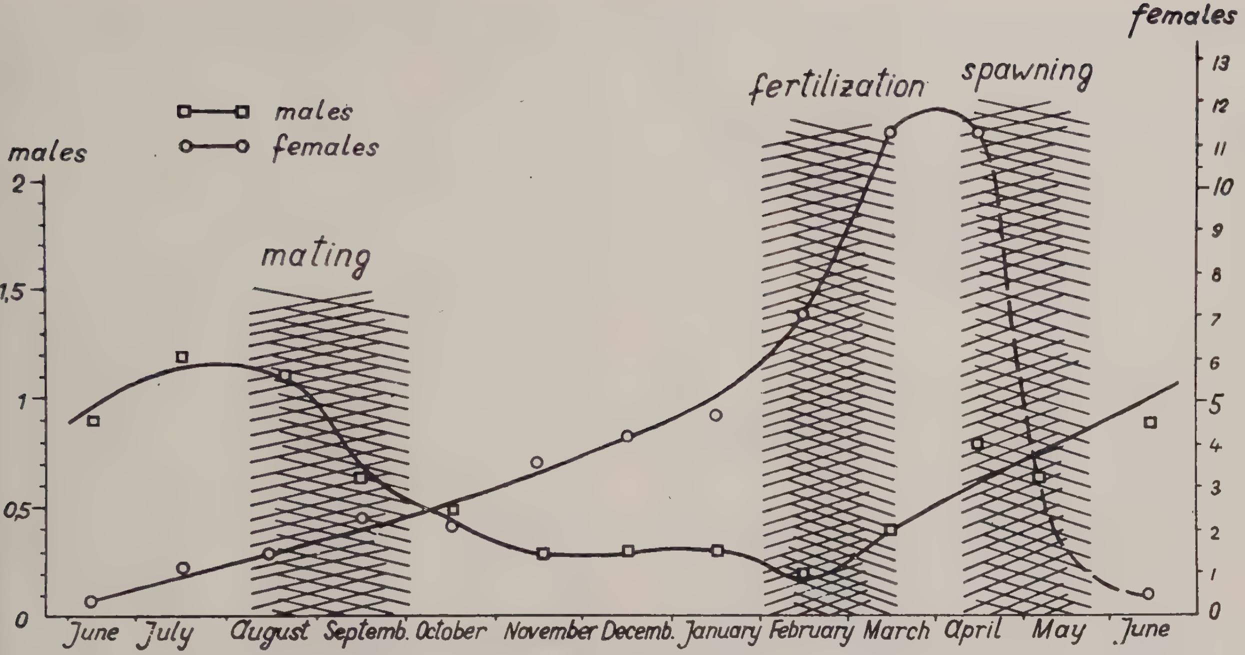

Figure 2. Changes in the maturity factor of the redfish (*Sebastes marinus* (L.)) males and females during the year (%).

caught during May, while in April they are rarely found. In June general transformation of the spermatids into spermatozoa is observed. The spermatocysts begin discharging sperm into the lumen of the ampullae and ductuli efferentes. The number of spermatocysts with fully formed spermatozoa increases continually; the amount of sperm in the lumen of the ampullae and ductuli efferentes also increases. By August spermatogenesis has ceased. All spermatogonia, which have begun to divide, are transformed to spermatozoa. Ductuli efferentes and ductus epididymidis are filled with sperm; the male is capable of copulation. Insemination takes place on the feeding grounds between August and October. The period of copulation indicated above does not coincide fully with the period reported by J. Magnússon. It may be that the two populations observed were of a different ecological character. The copulation period varies, probably owing to the circumstances obtaining at the time of spermatogenesis.

The spermatozoa lie in the ovaries in the condition of physiological rest, influenced — as J. Magnússon supposed — by a secretion produced within the bladder of the male. Spermatozoa remain in this resting state until the oocytes have ripened and ovulated (February/March). Ripening and ovulation are effected by changes in the pH of the ovarian fluids. According to the measurements of pH obtained from this material, pH changes from 6·5 to 7·0. As a result the resting spermatozoa become active, and the oocytes are fertilized.

A cross-section of a testis during the period following copulation clearly shows two zones, a peripheral and a central one. The peripheral zone contains the empty ampullae after the discharge of sperm. In the central zone the ductuli efferentes, ductus epididymidis and part of the ampullae still contain sperm. Several specimens at this period (September) show the presence of some mitosis of spermatogonia undergoing division, but such testes occur only rarely. The remainder of the spermatozoa in the testes undergo phagocytosis. The role of phagocytes is played by epithelial cells lining the ductuli efferentes and ductus epididymidis. On the cut sections plasmatic bulges can be seen "seizing" the spermatozoa with which the ductuli are filled. The duration of phagocytosis of the spermatozoa varies. It coincides to some extent with the feeding period, but occurs mainly during the winter migrations. In the major part of the testes observed, phagocytosis was found to end by January/February. But there were some testes (May, 1954) in which spermatozoa of a new generation had been formed; at the same time the ductus epididymidis contained "old" sperm, undergoing phagocytosis.

By early October, secondary and later spermatogonia have already appeared in the spermatocysts, first in the peripheral zone of the testes. In November testes sections sometimes show spermatocysts containing spermatids. Thus, during the winter migrations of the males, two processes are going on simultaneously in the testes: phagocytosis of the "old" sperm and a new wave of spermatogenesis. In December/January, intensity of

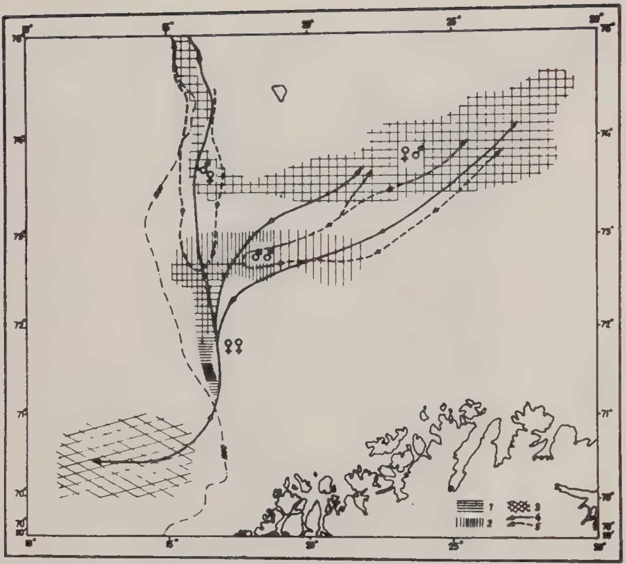

Figure 3. Diagram of migrations of *S. mentella* Travin.
1 = females
2 = males
3 = "spawning" areas
4 = migrations of females
5 = migrations of males

spermatogonal division increases and over all the testis spermatogonia of later stages can be observed. Spermatocysts with spermatids are by no means infrequent. In February spermatid formation intensifies, and by March it reaches its height. Figure 2 shows how the relative weight of the testes (m.f.) changes during the year.

Investigations have also been made into the history of gametogenesis of the *S. mentella*. Comparison of the data obtained showed that gametogenesis and m.f. are very similar for both species. It has been possible, however, to discover that the duration of gametogenesis is influenced by the ecological differences of the species reported by Travin (1951). It has been found that spermatogenesis and oogenesis terminate earlier in *S. mentella* (Bear Island–Spitsbergen populations) than in *S. marinus* (inhabiting the Barents Sea). In 1959 this difference was at least one month.

As has been shown by Travin, the habitats of *S. marinus* and *S. mentella* are different and so are their routes of migration. A schematic chart of *S. mentella* migrations (Fig. 3) has been drawn, based on the data collected by scientific workers of PINRO since 1946, (V. I. Travin, N. A. Khaldinova, T. S. Berger, A. S. Baranenkova, V. P. Sorokin). The feeding areas of *S. mentella* include deep-water areas of the Western Deep (to the east and south-east of Bear Island), the southern and western slopes of Bear Island Bank, and the area northwards along the continental slope, including the West Spitsbergen area. Here *S. mentella* lives from June/August until February/April. In August/September insemination of the females takes place; during January/February and partly in March, the oocytes ripen and are fertilized, and this coincides with the beginning of the active "spawning" migration of females to the "spawning" areas. The migration of males begins approximately a month later than of females.

In 1959 the migrations of females reached their height by February, whereas mass migrations of males were observed only at the end of March. At this time the formation of unisexual shoals takes place.

From the Spitsbergen area and the western slope of the Bear Island Bank, *S. mentella* moves southward along the slope; from the Western Deep area the fish move in a westerly and south-westerly direction, keeping to depths greater than 350 m. "Prespawning" female concentrations of *S. mentella* are already being formed at the beginning of March in the south-west part of the Kopytov region. This area lies between 71°50′–72°20′N, 15°00′–16°30′E. The ovaries of females caught in this area contain embryos with the eyes pigmented; the body is segmented and there are chromatophores on the ventral and dorsal side of the caudal part of the body. The latest stage of embryo development observed in the area of "prespawning" concentrations can be characterized as follows: body length, 7·7 mm; eye pigmentation is complete; numerous chromatophores are present on the dorsal and ventral sides of the body; the alimentary canal and the occipital region are pigmented. The pectoral fins are formed and the rays of the caudal fin can be seen. The embryo lies in the egg membrane. Females with such embryos pass to the areas of liberation of larvae.

Material collected over several years by Baranenkova and others (1956) on the distribution of redfish larvae, as well as the samples taken in 1959, indicate that liberation of larvae by the females of the Bear Island/Spitsbergen populations of *S. mentella* takes place in the area between 70°–71°N and 11°–16°E.

In 1959 the liberation of larvae belonging to this population began between 25. April and 2. May. During liberation *S. mentella* females are not found in concentrations suitable for commercial fishing. After liberating the larvae the females migrate to the feeding grounds via the same route.

The *S. mentella* males do not undertake such long migrations. They remain in the northern part of the Kopytov area, north of 72°20′N. In early spring (March) shoals of males are observed at 25°E. In due course they move to the west, and by June reach 15°E. With their advancement to the west their concentration increases; the greatest density of shoals of males is observed in April. Throughout the whole migration period the concentrations of *S. mentella* males are fished intensively by the trawl fishery.

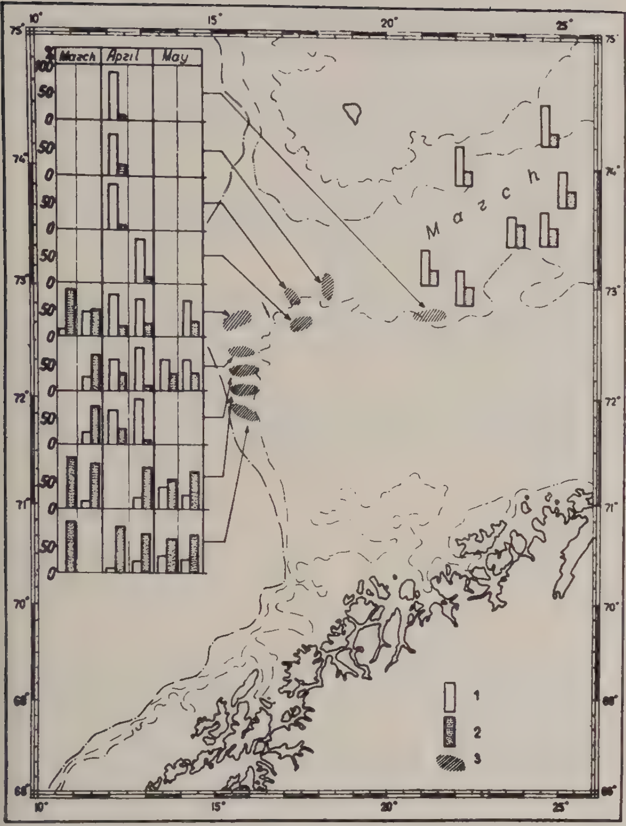

Figure 4. Sex ratio dynamics of the *S. mentella* Travin population during the 1959 spring migration.
1 = males 2 = females 3 = locality of capture

The migration dynamics can be clearly traced by the changes in the sex composition of the migrating stock. This is illustrated by Figure 4, where the results of three months' observations on the sex ratio variations during the spring period of the migrations (March, April, May) are summarized.

Summary

Redfish oogenesis and spermatogenesis take place in different seasons. Spermatogenesis is completed by August; then copulation takes place, resulting in the females' insemination. The spermatozoa are maintained in the ovary in a state of physiological rest until the moment of ripening of the oocytes, which occurs in February/March. Ripening and ovulation are accompanied by a pH change of the ovarian fluid, which results in an intensification of the spermatozoan activity and fertilization.

The extent of migrations of *S. marinus* and *S. mentella* is different. The spring migrations of females have a "spawning" character, the migrations of males are winter migrations. The summer/autumn migrations of both are associated with feeding. The formation of unisexual shoals takes place in February/March.

The bulk of *S. marinus* mature males inhabit the area eastward of the North Cape. *S. mentella* males generally inhabit the area north of 72°20′N. The males and females re-unite, after the liberation of larvae, in June–July, during their migrations to the feeding areas. The small number of males observed by Lüling in the Andenes, Langanes, Malangen areas (i.e. area of larval liberation by females, or the areas of prespawning concentration) does not signify, as Lüling thought, that males are in the minority in the *S. marinus* population but is the result of differential distribution brought about by different behaviour of males and females in the period of spring migrations.

The time of the migration of females to the "spawning" areas depends on the period of ripening of oocytes, their fertilization and subsequent embryonic development.

The duration and rate of migrations of males are determined by thermal conditions of the water masses in which they spend the winter. The time of the beginning of the males' and females' migrations may change; it is not necessarily the same in different years.

These investigations permit the conclusion that the sex ratio in a redfish population, not subjected to fishing, is unity (1·1).

The actual redfish fishery results in an upsetting of the male: female ratio. Many years' exploitation of the shoals of female *S. marinus* in the Lofoten Islands area has resulted in a reduction of females. The intensive fisheries for male *S. mentella* belonging to the Bear Island/Spitsbergen population has resulted in a reduction of male *S. mentella*.

The general biological timing of the annual cycle of the redfish, as established with respect to *S. marinus* and *S. mentella* populations of the Barents and Norwegian Seas, is apparently also valid for other *Sebastes* species accomplishing seasonal migrations.

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3.

Sex Ratio of Catches of Redfish and Migration

By

JAKOB MAGNÚSSON

Atvinnudeild Háskólans Fiskideild, Reykjavík

Abstract

An attempt is made to outline the migration of redfish in East Greenland, Icelandic, and Canadian waters. This study is based upon the sex ratio of catches of redfish at different times and localities in these areas. The following results were attained:–

(1) The redfish can appear in shoals consisting mainly of one sex.

(2) The separation of sexes can depend on locality and depth.

(3) The forming of such shoals may be independent of differences in depth and locality.

The following considerations on the migrations of redfish were made:–

(1) The female redfish at the NW and W coasts of Iceland seem to migrate southwards from these places for "spawning".*

(2) In East Greenland waters there are great nursery grounds for redfish. The ripening redfish migrate to the slopes of these grounds.

(3) When the fish reaches sexual maturity, the females assemble in shoals on the slopes, often in definite depths, just before spawning time.

(4) During the spawning period the females have, for the greater part, left these assembly grounds in order to migrate to the spawning places, or they become pelagic. However, spawning also takes place, at least partly, on the slopes where the required conditions are found.

(5) Immature fish and males do not appear to take part in the spawning migration.

(6) There seems to be a movement of immature fish and males southwards along the continental shelf of East Greenland.

(7) It is assumed that the females migrate southwards to the Irminger Sea for spawning. References are made to the two main areas in the Irminger Sea, where concentrations of plankton are found. One area is located off the SW coast of Iceland, the other off the SE coast of Greenland. The possibility that the main spawning places for redfish may coincide with these planktonic regions is discussed, and also, that the East Greenland redfish might prefer the area off SE Greenland for spawning.

(8) The females do not return immediately after spawning to the grounds in East Greenland waters.

(9) However, it must be assumed that the females return to these places in autumn for copulation.

On the Labrador and Newfoundland banks the following conditions are found:–

(1) As at East Greenland, the females of the Hamilton Inlet Bank seem to have a greater tendency to migrate from shallower to greater depths than the males. Most probably they also migrate away from the Bank for spawning purposes.

(2) At the Ritubanki (off Newfoundland) the spawning seems to take place on the slopes of the continental shelf.

Finally attention is drawn to the fact that the whole material discussed in the paper consists exclusively of redfish caught by bottom trawl and also to the possible errors in the conclusions which this method of sampling might cause.

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* Here the term "spawning" is used for the extrusion of larvae.

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SECTION V

AGE AND GROWTH

Discussion Leader: G. ROLLEFSEN

The meeting commenced with a demonstration by various experts of otoliths of redfish and of methods for reading otoliths.

The following papers had been tabled and were reviewed:–

Gulland, J. A. "A note on the population dynamics of the redfish with special reference to the problem of age determination."

Hansen, P. M. "Studies on the growth of the redfish (*Sebastes marinus*) in Godthåb Fjord Greenland."

Kelly, George F., & Wolf, Robert S. "Age and growth of the redfish (*Sebastes marinus*) in the Gulf of Maine". (Fish. Bull. No. 156).

Kelly, George F., & Barker, Allan M. "Observations on the behaviour, growth, and migration of redfish at Eastport, Maine."

Sandeman, E. "A contribution to the problem of the age determination and growth-rate in *Sebastes*."

Surkova, E. I. "Redfish, growth and age."

Trout, G. C. "The growth of immature *Sebastes viviparus* (Krøyer) from the Norwegian coast."

Trout, G. C. "The otolith of group 0 *Sebastes mentella* Travin."

A general discussion of the papers followed, however, with special reference to the following subjects:– (1) Age, (2) Growth, and (3) Maturity.

1. Age

Whilst it was generally agreed that both otoliths and scales were adequate for estimating age for young fish, it appeared from the discussions that sections of otoliths were most commonly used. It was recommended that scale/otolith comparisons and exchanges be carried out.

It was the consensus of the group that due to the long duration of the extrusion period and to the differing length of the pelagic stage, differences could arise in defining the first annual zone.

The age of *Sebastes viviparus* appears to be easily readable up to a comparatively old age.

For *marinus* and *mentella* the reading of the age of the older fish especially (from about the onset of maturity) was often found to be difficult. There is a need for the improvement and standardization of the technique of otolith-reading and for basing age determination upon criteria obtained from collections of young stages from the appropriate area.

2. Growth

After a thorough examination of the problem of growth and after having considered the evidence brought forward by the various experts the group agreed:

> that for the purpose of the study of population dynamics the conception of the slow growth of *marinus* and *mentella,* as advocated by a number of the experts, should be accepted.

It was noted that the papers presented included a series of data on growth-rates for different species of *Sebastes* from various regions of the North Atlantic, and the group recommended:

> that these data be used as a guide for the scientists working on the assessment of ICNAF redfish stocks.

3. Maturity

The onset of maturity could be connected with the attainment of certain lengths by males and females, the lengths differing from population to population.

Specific information on lengths at first maturity was presented for a number of populations during discussion.

The further discussions revealed that more material bearing on this subject could be made available from the files of the laboratories engaged in redfish research.

From the papers tabled and from the considerations in the meeting it was noted that the onset of maturity resulted in a change of the behaviour pattern, causing segregation and in some areas also migrations. Therefore, with the onset of maturity, the availability of the different sizes of fish, and of the two sexes, changed throughout the habitats of the population, i.e., on the nursery grounds of the immature fish as well as in the feeding and spawning areas of the mature fish.

1.

A Note on the Population Dynamics of the Redfish, with Special Reference to the Problem of Age Determination

By

J. A. GULLAND
Fisheries Laboratory, Lowestoft

An important part of research of any commercially exploited stock is to detect whether fishing is having a measurable effect on the stock, and if so, to assess the effect on both stock and catches of any changes in the fishery due e.g. to expansion or regulation. It is rarely, if ever, possible to say that any study is completely irrelevant to this problem; for instance it is important to know whether growth or natural mortality is likely to change appreciably with changes in abundance, and for this, knowledge of the absolute abundance of food organisms and the extent of parasitism and disease is entirely relevant. However, not all possible lines of research can be pursued at once, and where the "over-fishing problem" is a real one, it is surely vital to follow those lines of investigation which will enable at least an approximate assessment to be made, rather than those which at best are of secondary importance in assessing the effect of fishing.

Two questions about the redfish have attracted great attention, the question of growth-rate, and that of race, subspecies, or species. Obviously it is desirable to be sure of the correctness of age determination, and hence of the subsequent analyses in the form of age compositions, mortalities, etc. It is possible though that the final result in the form of the estimated effect of fishing, or result of regulation, may be close to the true value even when the age-length relation used is badly wrong. This is because the age determination affects not only the estimated growth pattern, but also the estimates of mortality rates, both due to fishing and to natural causes. In effect, the time-scale is distorted if age determination is incorrect, but so long as the same time-scale is used throughout, i.e. no data such as marking returns concerning mortality rates, etc., are used which do not involve the age determination at least implicitly, the final yield curves are unaltered. This was of course clearly brought out at the ICNAF meeting at Biarritz (Holt, 1958, pp. 36–37). This is a special case of the general principle of using the same assumptions throughout the analysis (Beverton and Holt, 1957, p. 180), which can give virtually the correct answer even when the assumptions are not correct; cf. Beverton and Gulland (1948) for assumption of complete mixing.

As shown by Parrish (1957) the discrepancy between the interpretation of redfish otoliths, whether or not zones should be grouped, is essentially a difference in the value of *K*, the parameter in the Bertalanffy growth equation. Thus under the slow growth hypothesis, the growth parameter K for redfish $= 0{\cdot}1$ or less, and the apparent age composition corresponding to that growth-rate gives a low mortality, say $Z=0{\cdot}5$ or less, while the fast growth gives $K=0{\cdot}2$, $Z=1{\cdot}0$. It is not quite so obvious how the separation of Z into F and M is affected, but if, as is often done, F and M are estimated by relating changes in Z to changes in total effort, the ratio of $F{:}M$ will be the same whether $Z=0{\cdot}5$ or $Z=1{\cdot}0$. More generally, Beverton and Holt (1959) have shown that for a wide range of species of fish K and M are quite closely proportional. Thus the set of estimates obtained, supposing the stock is heavily or lightly fished, might be as shown in Table 1.

Table 1

	Heavy fishing		Light fishing	
	Growth			
	Fast	Slow	Fast	Slow
K	0·2	0·1	0·2	0·1
F	0·8	0·4	0·2	0·1
M	0·2	0·1	0·8	0·4
Z	1·0	0·5	1·0	0·5

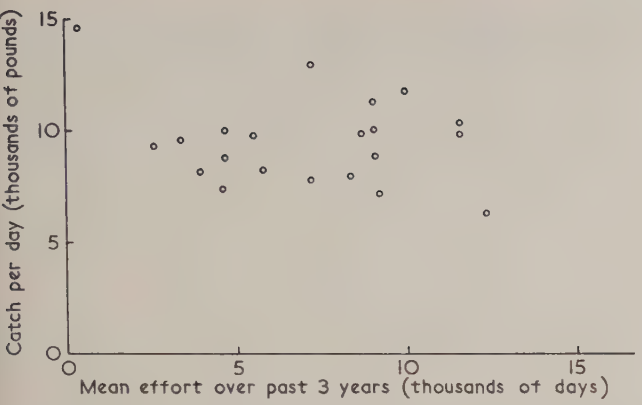

Figure 1. Plot of density of Gulf of Maine redfish, as measured by the catch per day, against the average effort during the past three years.

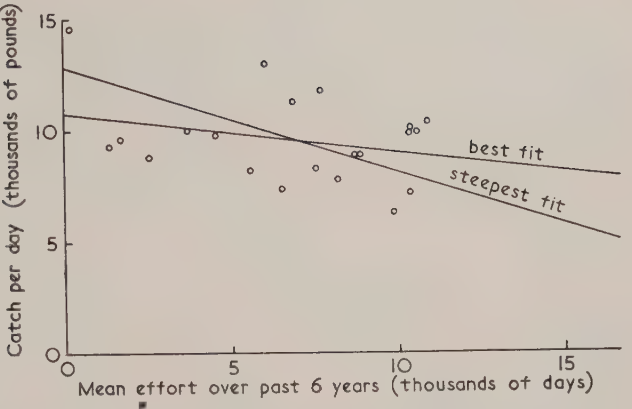

Figure 2. Relation between density of redfish and effort over the past six years. Showing (a) the line fitted by least squares, and also (b) the line giving the greatest probable slope, i.e. slope two standard deviations greater than (a).

Though Parrish (1957) did not consider this relation between apparent mortality and assumed growth-rate, his diagrams can be used to illustrate the effect. Considering first the yield : fishing mortality relation; extreme slow growth is illustrated by the curves for $K=0\cdot 1$, $M=0\cdot 1$, $t_c=6$, and fast growth by $K=0\cdot 6$, $M=0\cdot 4$, $t_c=1$ (i.e. in both cases recruitment occurs at the same size). (The illustration is not exact, since the ratio $M:K$ is not the same; however, the discrepancy is small.) Suppose that the present fishing rate corresponds to $F=0\cdot 4$ or $F=2\cdot 0$ for the two possible growth-rates, in both cases the yield would be a maximum at about one-third of the present effort, giving a yield some 25 % above the present level. Similarly an approximate pair of corresponding curves of yield against age (size) at recruitment are given by $K=0\cdot 1$, $M=0\cdot 1$, $F=0\cdot 3$; $K=0\cdot 6$, $M=0\cdot 4$, $F=0\cdot 1$. Suppose that the present size at recruitment corresponds to $t_c=6$ or 1 in the two cases. Then in both cases the greatest yield (some 30 % up to the present) would be obtained with an age at first capture double the present, which, of course, implies for both growth-rates the same size of fish at first capture, and hence the same selectivity of gear. The vital quantity for which an estimate is needed is not the absolute values of F and M, but the ratio $F{:}M$ or the ratio $F/F+M$ (e.g. Allen, 1953). Although methods do exist for estimating this in a stable fishery, estimation is much simpler when there have been large changes in the amount of fishing, and in particular when data exist for a near-virgin stock. In this case statistics of catch and effort alone may enable an assessment to be made, especially of the effect of effort changes (cf. Schaefer, 1954). Thus data given by Davis and Taylor (1957) enable an assessment of the effect of effort changes to be made. They gave, in graphical form, figures of catch and catch per unit effort for the Gulf of Maine redfish for the years 1935–1955, from which the corresponding figure of effort could be at once obtained. As the effort had been continually changing, a direct plot of catch per unit effort (or catch) against effort will not give the relation to be expected under steady conditions. The catch per unit effort in any year will depend not only on the effort in that year, but on the effort in the preceding year – in fact for as many years as the oldest fish in the stock has been vulnerable to fishing. However, the main effect will be from the effort in more recent years, to which most of the fish in the stock have been exposed. Accordingly, the mean effort over the past 3 and 6 years was calculated from Davis and Taylor's data (taking the pre-1935 effort as zero), and the catch per unit for the year has been plotted against the mean effort (Figs. 1 and 2). For the 3-year period no significant relation emerged, but for the 6-year period there is a regression, though barely significant ($P=0\cdot 1$). This relation will be approximately the relation between catch per unit effort and effort in a steady state. The regression line fitted by least squares has been drawn, and also the steepest possible line, i.e. the one with slope $b+2s_b$ where b=slope of best fitting line, s_b=standard deviation of b. This line is the one showing the greatest probable effect of fishing on the stock. Corresponding to these lines the two parabolas giving the relation of catch to effort in the steady state have been drawn (Figure 3). This shows that most probably increased effort will give increased yield up to an effort of thirty thousand days, i.e. three times the average load in the 1940's ,though possibly the maximum yield occurs at efforts as low as fourteen thousand days. From the isopleths of Davis and Taylor this would correspond to a fairly high value of M. Following the method of comparing observed and computed yield changes used by Cushing, for the herring,

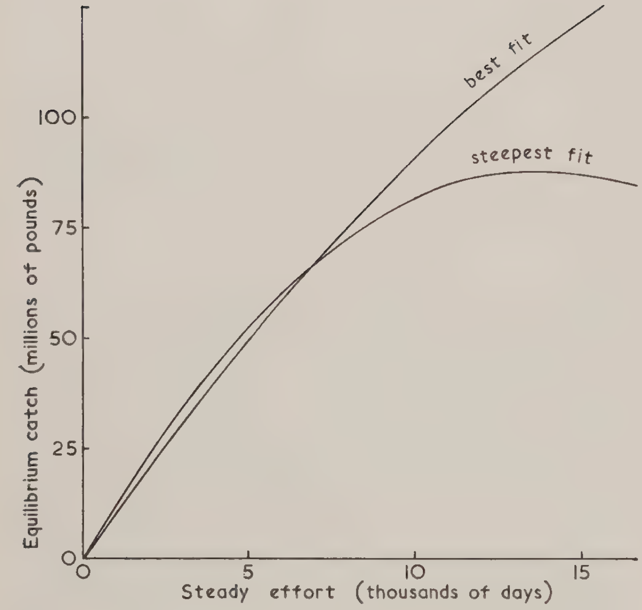

Figure 3. Relation between catch and effort in the Gulf of Maine redfish in the steady state; showing the most probable relation, and the relation with the maximum probable effect of fishing.

length composition (Baranov, 1918), numbers per unit we can compare the yield-effort curve so obtained with those obtained from the usual methods for a range of *M*, and hence estimate (*M*). This in turn can be used to give a yield-size at first capture curve.

However, length composition of the landings will enable much more accurate assessments to be made of both effort and selectivity (Gulland, in preparation); for instance the drop in catch per unit effort during heavy fishing should be most pronounced for the big fish, and negligible for the smallest, as has occurred (Perlmutter, 1953). Though the exact method used may vary, all depend on relating changes in total mortality, or related functions such as the slope of the effort, or mean length (Beverton and Holt, 1954) to changes in effort. The common factors are effort statistics and length data (which can readily be converted to age when the age-length relation is known). While later data on the age-length relationship can be used to deduce age compositions from past length data, e.g. of the near-virgin stock, no subsequent investigations on a heavily exploited stock can replace data on the size composition of the near-virgin stock, and it is these factors – effort and length composition – that are at present most urgent. For redfish, as indeed for many species of fish, there is a close relation between size of fish and depth of fishing. Special attention must be paid to the depth of fishing, not only of the sampled catches, but of the commercial fishery generally, as a change in depth may be equivalent to a change, possibly large, in selectivity.

The other major redfish problem is that of "races". For complete knowledge of the redfish fishery the understanding of the exact taxonomic status of each group of fish is valuable. For the present the vital question is whether or not the groups can be assessed as a single stock. This will depend first on whether by differences in behaviour or distribution they are fished independently, and secondly the differences, if any, in the values of their parameters used in the yield equations. Of these the most important are likely to be ***F***, the fishing mortality, and $L\infty$, the asymptotic size, particularly if the latter for one group of fish is near the selection size. A major danger is that differential fluctuation in the abundance of two races with very different $L\infty$'s will be interpreted as effect of fishing on length composition of one stock. Once it is known that such differences exist and are important, then the groups of fish must be analysed separately, regardless of their taxonomic status. Thus if the males and females differ appreciably in growth pattern or mortality, for accurate assessment, at least of situations greatly different from the observed, the males and females have to be treated as separate stocks and assessed separately; cf. Davis and Taylor (1957).

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2.

Studies on the Growth of the Redfish (*Sebastes marinus*) in Godthåb Fjord, Greenland

By

PAUL M. HANSEN

Greenland Fisheries Investigations, Charlottenlund, Denmark

During surveys for prawn grounds in the Godthåb Fjord in 1946, an area suitable for prawn trawling was found in the Pisigsarfik branch of the Fjord (64°23′N, 50°23′W); the depth was 220–250 m and the bottom was clean ooze. In the following years trawling was often carried out in order to provide material for the study of the biology of *Pandalus borealis*. The catch included, besides the prawn, various species of fish, mainly redfish. A total of 65 hauls was made from 1946 to 1959 with the shrimp trawl (18 mm meshes) and 51,000 redfish resulted from all the hauls.

All redfish caught were measured to the nearest cm below, from the snout to the distal margin of the tail fin. The sex was not determined. A number of samples of otoliths were collected, covering various sizes of fish, but they have not yet been examined for age.

Figure 1 illustrates the percentage size distribution of all samples from 1946–59. The total length of most of the redfish varies between 10 and 25 cm. Only few specimens reach more than 40 cm. The figure shows that the length curves have pronounced peaks, and that these peaks gradually move to the right in the samples from month to month. When a peak appears for the first time it is of 7–9 cm. In some cases the peak can be followed through the curves for the various samples right up to the length of 25 cm. It is obvious that these peaks represent year-classes. The question of which year-classes the peaks represent when they first appear remains, however, open.

As reported earlier to ICES and ICNAF (Hansen, 1957, 1958a, 1958b, 1958c, 1959) there are reasons for assuming that the peak of 7–8 cm represents the age-group II. In the following year this peak has moved to 10–12 cm, which then should be the size of the III-group. Next year again the peak is at 13–15 cm, corresponding to the IV-group.

Figure 2 demonstrates growth curves for various year-classes. The ordinate indicates length in cm; the abscissa the years 1952–59, subdivided into months. The points represent the separate peaks of the length curves. Each point represents the average calculated from three points on the length curve following one another, the central one being doubled. If the peak is at the a cm, the two nearest points are a_{-1} and a_{+1} cm; x, y and z being the numbers of redfish of a_{-1}, a, and a_{+1}, the average is calculated as follows

$$\frac{a_{-1} \times x + 2a \times y + a_{+1} \times z}{x + 2y + z}$$

Each of the curved lines in Figure 2 are drawn so as to follow as closely as possible the peaks corresponding to one and the same year-class. These curves, thus, are to be considered as approximate growth curves for the separate year-classes.

In Figure 3 the same observations as in Figure 2 are arranged by age-groups. It is apparent that the deviations of the mean lengths for the various age-groups are smaller than might be expected. The drawn line represents in a way the growth curves for redfish from the locality where the data were collected. The mean lengths of each age-group are calculated to be as follows:–

II	III	IV	V	VI	
8·3	10·5	13·7	16·5	19·5	cm
VII	VIII	IX	X	XI	
22·2	24·8	26·4	28·0	30·2	cm

The mean lengths for age-group X and XI are not reliable as the data are very scarce. The yearly growth is calculated to be as follows:–

II–III	III–IV	IV–V	V–VI	VI–VII	
2·2	3·2	2·8	3·0	2·7	cm
VII–VIII	VIII–IX	IX–X	X–XI		
2·6	1·6	1·6	2·2		cm

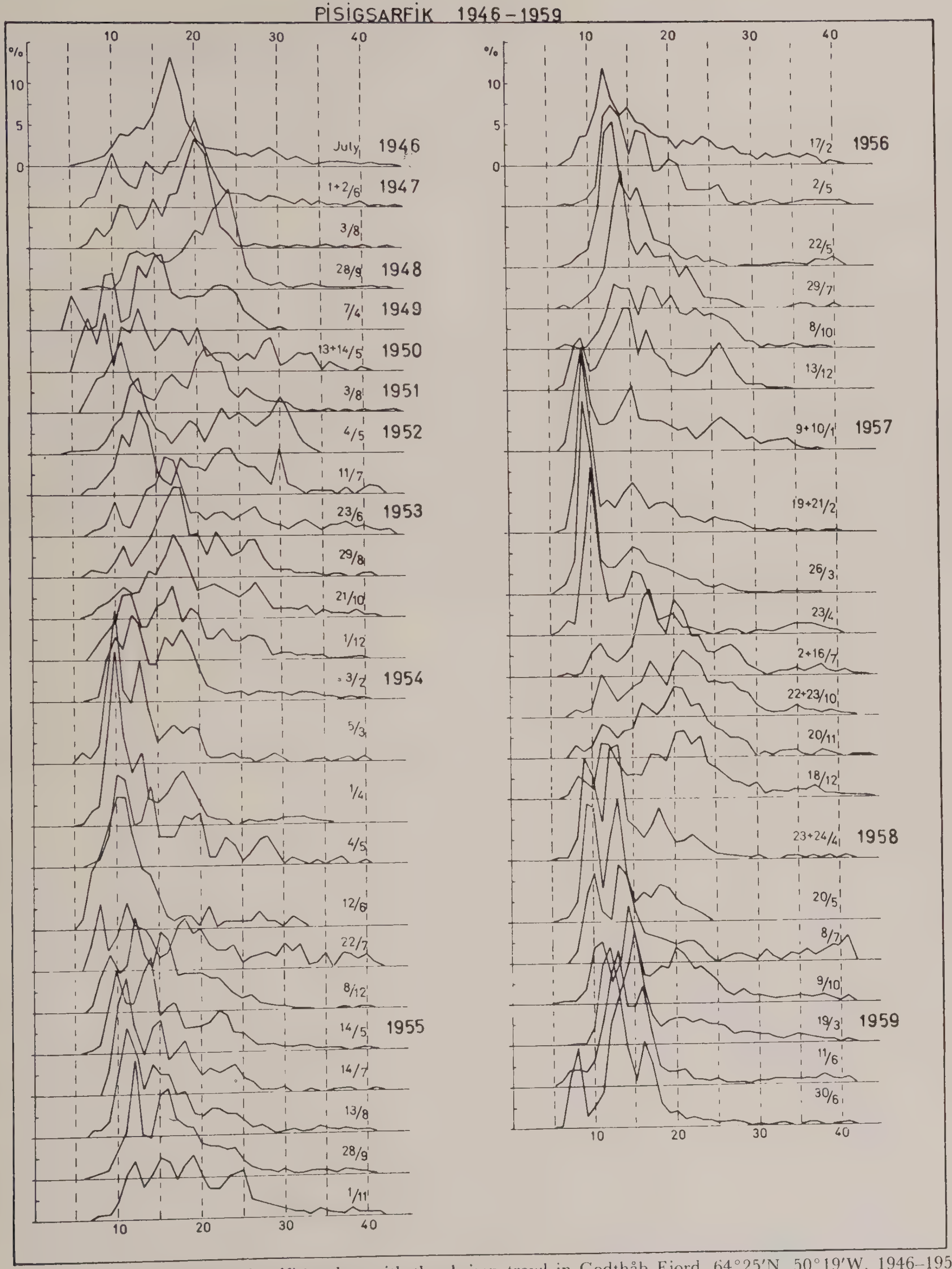

Figure 1. Length-frequencies of redfish taken with the shrimp trawl in Godthåb Fjord, 64°25′N, 50°19′W, 1946–1959.

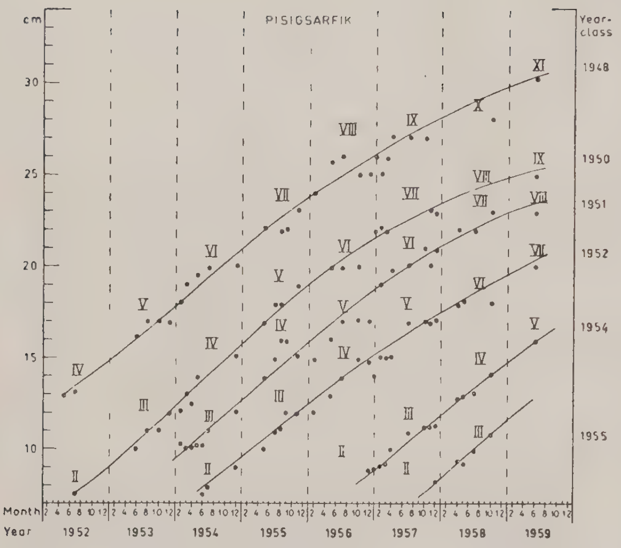

Figure 2. Growth curves for various year-classes of redfish.

From the preceding it appears that the growth of the redfish in the Godthåb Fjord is very slow, with a yearly increment of only 2–3 cm.

Bratberg (1956) has found the same slow growth of immature redfish based on scale readings for the region off northern Norway. The mean lengths found by Bratberg are nearly exactly the same as those calculated for the Godthåb material.

Tagging

By fishing experiments in the Godthåb Fjord an area was found in 64°14′N, 50°55′W where large redfish could be caught with jig at a depth of 20–30 m. When the fish was hauled in slowly it arrived on deck in a condition suitable for tagging. From this locality 143 redfish were tagged; in 1956, 75 specimens; in 1957, 27; and in 1958, 41 specimens. The Petersen disc was used, fixed to the gill cover. The fish so marked were lowered into the water in a steel basket turned upside down. In most cases it was only necessary to lower the basket a few metres before the fish swam briskly towards the bottom. In some cases, however, the fish had

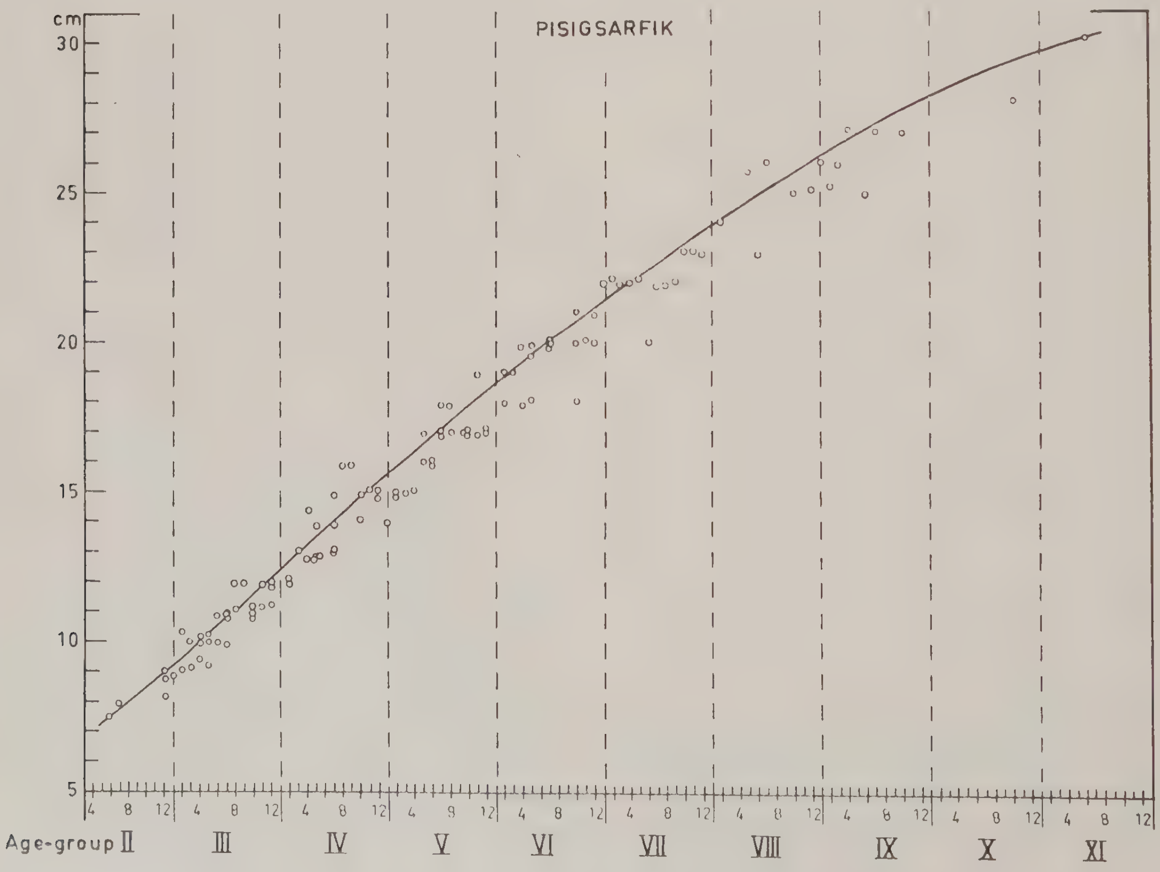

Figure 3. Growth curves for various age-groups of redfish (groups II–XI).

suffered too much from being brought to the surface; such specimens were, of course, not used for tagging.

Up to now four of the tagged fish have been recaptured. Unfortunately one of these recaptures was lost and another was measured incorrectly when recaptured (c. in the table). Two of the recaptures (a. and b. in the table) were delivered as whole fish to the laboratory in Godthåb. The data of the three specimens are as follows:–

	Date of tagging	Date of recapture	Sex	Length when tagged	Length when recapt.
a.	19. June 1956	5. March 1958	♀	54 cm	57 cm
b.	24. Aug. 1957	25. April 1959	♀	50 „	53 „
c.	23. Aug. 1957	16. June 1959	♂	50 „	(45) „

It is apparent that the interval between tagging and recapture is nearly the same for the three fish (624, 609, and 661 days), and a. and b. have grown about 3 cm. As two full years have not passed between tagging and recapture the yearly growth must be placed at a little more than 1·5 cm.

If the yearly growth from the 9th year is estimated at 1·8 cm and the lengths of the nine year-old fish at 26·4 cm, the age of a 53 cm long redfish may be estimated as 24 years, and that of a fish 57 cm long as 26 years.

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3.

Age and Growth of the Redfish (*Sebastes marinus*) in the Gulf of Maine*)

By

GEORGE F. KELLY and ROBERT S. WOLF

Abstract

Validity of the use of the otolith in age-growth studies of the redfish (*Sebastes marinus*) is demonstrated. Otoliths accrue one opaque and one hyaline band a year. The opaque band begins to form in April, the hyaline band in September. Otoliths preserved in ethanol may be read whole, although those from larger fish are more easily read after they are sectioned. Otoliths stored dry must be sectioned for reading.

Redfish larvae can be collected in surface waters throughout the period of spawning, April to September. The fry descend into mid-depths as they grow, and first appear on the bottom in August. Redfish reach an average length of about 50 mm in their first year of life.

The sexes grow at virtually the same rate until the tenth year, after which the male grows more slowly than the female. Redfish of the Gulf of Maine grow more slowly than those of northern European waters.

While dominant age classes appear in the collections of young fish, they are not obvious in samples of older, commercially available fish.

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* The full paper has appeared in the U.S. Fish. Bull., *60* (156): 1–31. Washington, 1959.

4.

Observations on the Behaviour, Growth, and Migration of Redfish at Eastport, Maine

By

GEORGE F. KELLY and ALLAN M. BARKER
Fishery Research Biologists
Bureau of Commercial Fisheries Biological Laboratory
Woods Hole, Massachusetts, U.S.A.

There has long been a need for better methods to resolve the questions concerning the growth and migration of *Sebastes marinus* (Linnaeus). Various growth-rates have been computed for different *Sebastes* stocks using age estimates from scales or otoliths, but there has been no direct evidence of the growth of individual fish to corroborate the estimates. Some of the computed growth-rates are so extremely low that their validity has been questioned, and in recent years a lively controversy has developed on the problem of redfish age estimation. The most promising method for obtaining the necessary information appeared to be a well designed tagging experiment.

Previous tagging attempts are known to have been made, but all had failed because of the difficulty in obtaining live fish from the deep water. Redfish are normally found in 40 to 200 fathoms in the vicinity of the Gulf of Maine, occasionally deeper to 425 fathoms (Schroeder, 1955). Fish brought up from even the shallowest of these depths are damaged by decompression and quickly die. This species seems to be more vulnerable to decompression damage than most other groundfish.

An inshore stock of redfish at Eastport, Maine, near the mouth of the Bay of Fundy, made the present study possible. The existence of this stock was first mentioned by Verrill (1871) in his descriptions of the fauna of the Eastport region. Huntsman (1922) also reported redfish in the St. Croix River and Passamaquoddy Bay. Neither record suggested anything more than an occasional appearance of small redfish in the area. On an exploratory field trip to Eastport in July 1956, fish as large as 25 cm were readily caught on hook and line. The redfish came near the surface around the docks and were caught and tagged without suffering obvious damage from decompression. Accordingly, an intensive tagging programme was designed to study growth and migration of these particular redfish.

At the present time the relationship of the Eastport redfish to other Gulf of Maine redfish is not clearly understood. The Eastport fish are considered to be a group of *Sebastes marinus* having a dark green-bronze or black tone masking the bright red colour of the typical deep-water redfish, but apparently similar to the deep-water fish in other characteristics.

The primary objectives of this study were; first, to make general observations on the behaviour of redfish, second, to obtain a direct measure of redfish growth, and third, to determine the migratory tendencies of redfish.

The topography of the Eastport shoreline consists of steep, stony beaches set between rocky outcroppings that drop off sharply into deep water. Much of the intertidal zone is overgrown with the rockweed *Fucus*. Docks are set on long wooden pilings extending out to the edge of the deep water. Numerous underwater rocky ledges line the slope of the shore beyond the mean low-water mark.

The shore is swept by strong tides causing a daily rise and fall of between 15 and 25 feet. The incoming tide from the channel north of Campobello Island presses close against the Eastport shore as it sweeps southward around the peninsula into Cobscook Bay (Fig. 1). The ebbing tide flows northward through the main channel but this northward flow does not press close against the Eastport shore. A large eddy from the ebbing tide usually predominates, causing a southward flow of water past the Eastport docks during the entire period of ebb tide.

The occurrence of redfish in Eastport harbour is apparently the result of the unusual hydrographic conditions that prevail there. The fauna of Eastport, first described by Verrill (1872), is similar to that of the offshore bottom areas of the Gulf of Maine. The westerly current along the New Brunswick coast, described by Mavor (1922), serves to concentrate pelagic fishes and invertebrates between the islands at the mouth of Passamaquoddy Bay. The euphausiid shrimp *Meganyctiphanes norvegica* appears there in vast swarms and is preyed upon by fish, whales, and sea birds during the late summer and autumn. There are no barriers to prevent redfish in the deep waters at the mouth of the Bay of Fundy from approaching the Eastport area through the deep channel at the north end of Campobello Island (Fig. 1).

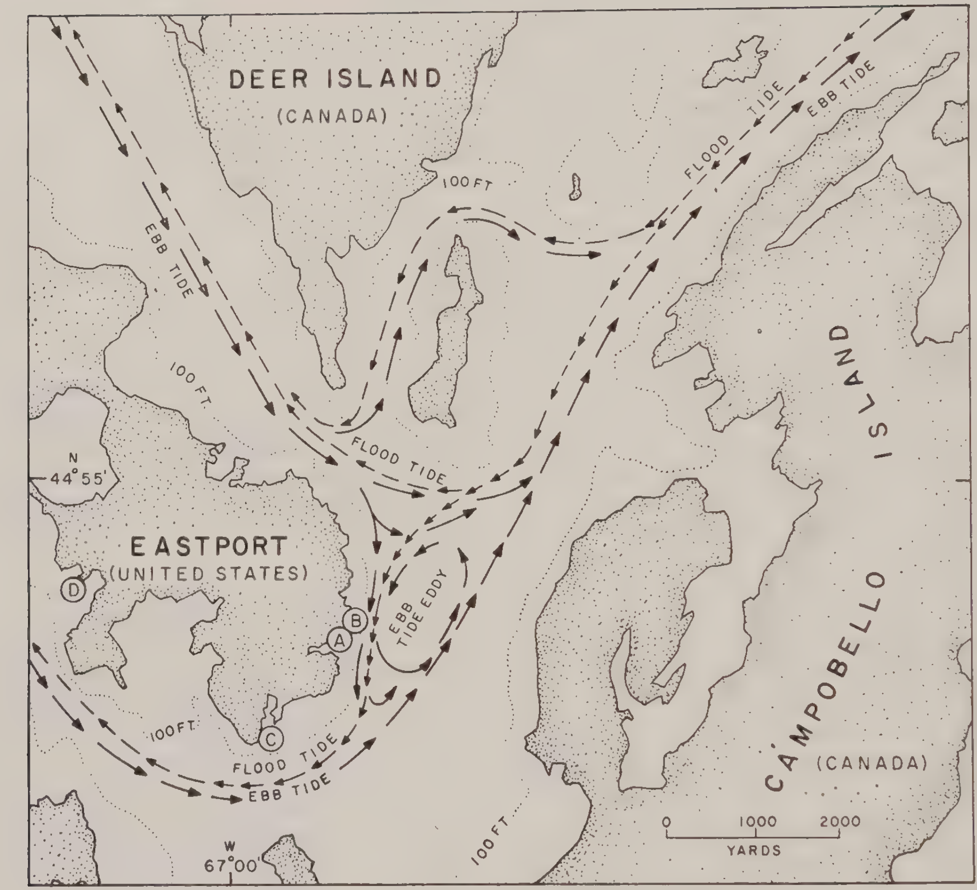

Figure 1. Tidal flow around Eastport, Maine.

Methods

Tagging operations began at Eastport in July 1956, and continued until August 1958, when the first phase of this study was completed. During that period almost 5,500 redfish were tagged. Monthly field trips were made for a year, less frequently during the remainder of the period. In July 1959 a sample of 250 tagged and untagged fish was collected for studies of the otoliths to determine the effect of tagging on the rate of growth. Redfish were collected and tagged at four locations in the Eastport area (Fig. 1). The best location was at the "old steamer dock" where, according to some of the older townsmen, redfish had appeared sporadically each summer for as long as one could remember. The location and construction of the dock apparently served to attract the redfish. It extended out into deep water farther than other docks and was built on a base of huge granite blocks set loosely together to form a wall rising about 20 ft from the harbour bottom. The wall simulated a natural rocky ledge with crevices into which the fish could move for shelter. Large electric lights set high on the dock illuminated the water, attracting swarms of shrimp to the area at night.

The bottom around the steamer dock was littered with rusting metal scraps which made the use of trawl nets impractical but did not interfere with hook and line fishing. This appeared to be the best collecting method under the circumstances. Although slow, it had the advantage of bringing fish up in good condition. Small barbless hooks were used to minimize the harmful effects of hooking. Fishing at the three alternate locations was limited to times when bad weather made it impossible to fish at the steamer dock.

Fishing was done mostly at night from a 40 ft power boat moored to the dock. The fish were held in floating live-cars alongside the boat until time for tagging. Daylight fishing was done occasionally along the channel edge about 300 yards off the dock to collect redfish from the deeper water.

The fish were tagged aboard the boat and released at the pier. A soft leather glove was worn on the left hand of the tagger to lessen the lacerations from the fin and head spines while handling the fish. Petersen disc tags were fastened to the left operculum with a red disc under the operculum and the serially numbered white disc on the outer surface, the two secured together with a stainless steel pin. Fork length was measured to the nearest millimetre.

Recaptured fish were measured and erosion damage to the operculum was noted. Tags were examined for deterioration, and faulty discs or pins were replaced.

During each fishing operation, surface and bottom water temperatures were taken with a reversing thermometer. In August 1956 a series of bathythermograph casts was made through the deep water of the channel to determine the degree of temperature stratification. At other seasons, surface and bottom temperatures were taken at two or three locations in the channel.

Results

General Observations

Cyclic variations

Activities of redfish seemed to be correlated with daily cycles of daylight and tide. Occasionally a few fish were seen and caught during the day, but usually they appeared only at night. They were most often observed and caught during calm weather, particularly on foggy or rainy nights. During windy weather when the water became choppy, redfish were virtually unavailable.

Feeding

Feeding was almost wholly nocturnal, the time varying each night with the stage of the tide. Although redfish fed primarily on the euphausiid shrimp, *Meganyctiphanes norvegica,* they were attracted to any freshly-cut animal bait. As darkness approached, a few redfish began feeding at the bottom, gradually rising during the evening until they were visible at the surface eating euphausiids. Under these conditions unwary fish were frequently taken in a dip net as they darted after euphausiids on the surface.

Redfish seemed to prefer low light intensity while feeding near the surface. When the euphausiids concentrated beneath the dock lights, redfish would feed at the edges of the illuminated area. If brighter lights were turned on, they quickly settled deeper in the water, returning again to the surface when the bright lights were extinguished.

Differences in the feeding habits of redfish and small pollack were observed when the two species were feeding together on concentrations of euphausiids. Schools of pollack darted about striking wildly at the shrimp and creating a great disturbance on the surface. The redfish fed individually, approaching the shrimp slowly and hesitatingly from beneath. With a quick, arching dart they would strike the shrimp at the surface and return below. Even when shrimp were present in vast swarms, the redfish never became frenzied but continued methodically to capture one individual at a time.

Redfish were similarly cautious when approaching a baited hook, examining it deliberately for a few seconds before gently taking it. Occasionally there was a brief competition between fish for the same bait, but usually the first fish to approach the bait was allowed to take it. The redfish did not hesitate to chase small pollack from the bait, but they did not attempt to prey on them.

Orientation behaviour

Water currents sweeping past the dock appeared to have a direct influence on activities of the redfish. The fish were most plentiful at the surface when tidal currents were at a minimum. Under these conditions the fish lay almost stationary in the water fanning their fins slowly. They might face straight up or down perpendicular to the water surface or lie tilted at an angle toward either side.

Redfish never appeared near the surface when the current was running swiftly or when the water was splashing hard against the dock. On several occasions when they were abundant in the calm water, they quickly disappeared and stopped biting when the current became swift or the surface choppy. If a pulse of swifter current swept along the dock, the fish entered crevices between the granite blocks. This action appeared to be a positive effort to avoid sudden changes in current.

When redfish came to the surface they stayed close to the face of the granite dock base and around the pilings. Their actions appeared to be part of a pattern of orientation to vertical surfaces. At times when they were almost clinging to the rocks, the dark, blotchy colour pattern served to conceal them. The whole attitude of the fish at such times suggested that this was a characteristic reaction to natural surroundings similar to what might be encountered around the rocky ledges of the offshore grounds.

Temperature tolerance

Redfish withstood temperatures higher than the approximate maximum of 48° to 50°F (8·9°–10·0°C) suggested by Bigelow and Schroeder (1953). The East-

Table 1

Summary of Eastport tagging operations listing monthly totals of catch, fishing effort, numbers tagged and recaptured, and range of water temperatures observed

Date	Water temperature °F	Water temperature °C	Number of days fished	Number of fish[1] caught	Number of tagged fish[2] recaptured	% tagged fish recaptured	Number of tagged fish released	Tagging location A	Tagging location B	Tagging location C	Tagging location D
1956											
July	48·2–51·5	9·0–10·8	4	317	0	–	317	317	–	–	–
Aug.	50·0–53·5	10·0–11·9	11	1,789	10	0·6	1,779	1,368	–	411	–
Sept.	51·5–53·0	10·8–11·7	9	1,424	153	10·7	1,271	1,049	–	94	128
Nov.	48·5–49·0	9·7–9·4	2	102	25	25·0	18	18	–	–	–
1957											
Feb.	34·5–35·0	1·4–1·7	2	0	0	–	0	–	–	–	–
May	42·0–43·2	5·6–6·2	1	25	12	48·0	0	–	–	–	–
June	46·5–50·5	8·1–10·3	4	411	110	26·8	301	51	226	–	24
July	49·8–53·8	9·9–12·1	7	949	295	31·1	654	374	227	–	53
Aug.	51·2–55·0	10·7–12·8	7	1,043	459	44·1	585	471	109	–	5
Oct.	52·0–52·0	11·1–11·1	4	100	72	72·0	28	28	–	–	–
Nov.	49·0–49·4	9·4–9·7	2	335	162	48·4	108	108	–	–	–
Dec.	44·0–44·5	6·7–6·9	2	135	57	42·2	78	78	–	–	–
1958											
Jan.	41·2–41·3	5·1–5·2	1	1	1	100·0	0	–	–	–	–
Feb.	36·5–37·0	2·5–2·8	2	27	10	37·0	17	17	–	–	–
Mar.	37·2–38·0	2·9–3·3	3	58	30	51·7	28	28	–	–	–
May	40·7–42·0	4·8–5·6	4	128	61	47·7	67	67	–	–	–
June	44·8–46·0	7·1–7·8	3	166	126	75·9	40	40	–	–	–
July	48·5–49·5	9·2–9·8	4	361	306	84·7	55	–	–	–	55
Aug.	51·9–53·0	11·1–11·7	4	795	694	87·3	101	33	–	–	68
Totals			76	8,166	2,583	31·6	5,447	4,047	562	505	333

[1] Includes tagged fish
[2] Includes multiple recaptures

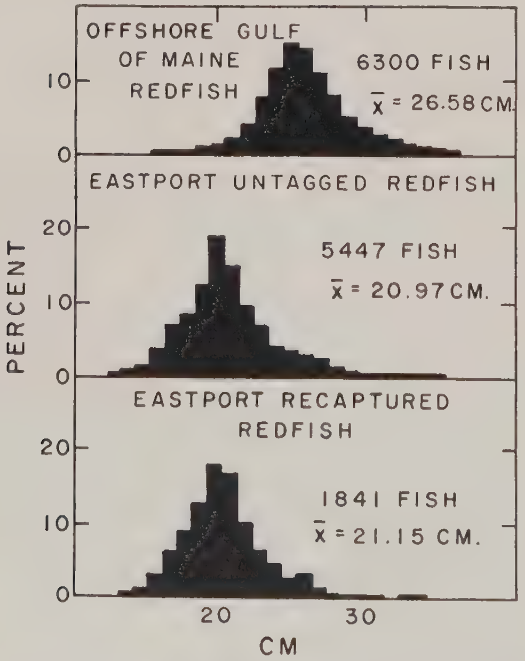

Figure 2. Length composition and mean length of offshore Gulf of Maine and Eastport redfish.

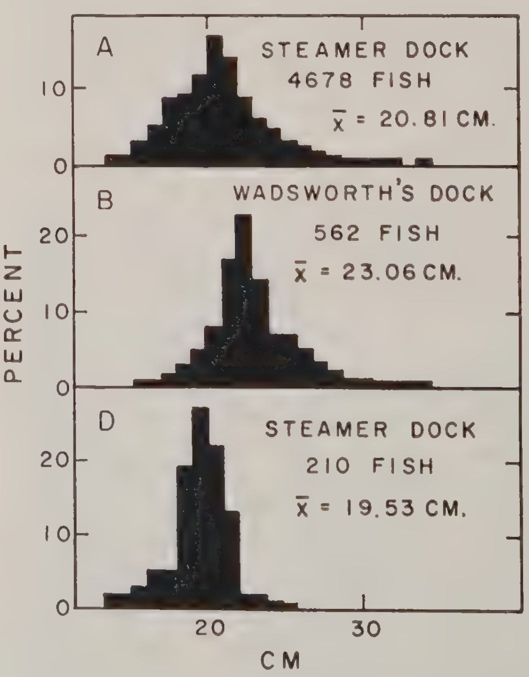

Figure 3. Length composition and mean length of untagged redfish from locations A, B, and D at Eastport.

Table 2

Length-frequency of Eastport tagged redfish at time of release

Length (cm)			1956						1957			
	July	Aug.	Sept.	Nov.	Total	June	July	Aug.	Oct.	Nov.	Dec.	Total
12·6–13·5	1	9	8	–	18	–	2	3	–	1	–	6
13·6–14·5	–	16	20	–	36	–	14	4	1	2	2	23
14·6–15·5	5	22	17	–	44	2	18	5	–	–	4	29
15·6–16·5	8	71	39	1	119	7	33	34	–	2	1	77
16·6–17·5	15	137	94	2	248	5	37	36	3	10	10	101
17·6–18·5	24	114	151	5	294	15	63	46	3	12	12	151
18·6–19·5	61	246	171	1	479	24	70	67	3	12	9	185
19·6–20·5	85	408	275	–	768	37	93	62	3	17	5	217
20·6–21·5	38	274	237	3	552	52	80	71	7	10	4	224
21·6–22·5	23	145	88	1	257	52	91	86	2	10	6	247
22·6–23·5	17	98	51	4	170	36	55	70	1	12	5	179
23·6–24·5	17	56	34	1	108	15	29	34	–	4	4	86
24·6–25·5	7	69	24	–	100	16	32	17	–	2	5	72
25·6–26·5	7	53	19	–	79	16	16	22	2	3	1	60
26·6–27·5	4	25	19	–	48	11	7	14	2	5	4	43
27·6–28·5	4	17	7	–	28	8	4	5	–	3	3	23
28·6–29·5	1	10	6	–	17	2	3	2	–	2	–	9
29·6–30·5	–	5	6	–	11	1	5	3	–	1	1	11
30·6–31·5	–	3	2	–	5	1	1	1	1	–	–	4
31·6–32·5	–	1	1	–	2	1	–	–	–	–	2	3
32·6–33·5	–	–	–	–	–	–	1	1	–	–	–	2
33·6–34·5	–	–	1	–	1	–	–	2	–	–	–	2
34·6–35·5	–	–	1	–	1	–	–	–	–	–	–	–
Number of fish	317	1,779	1,271	18	3,385	301	654	585	28	108	78	1,754
Average length	20·9	20·9	20·6	20·5	20·8	22·4	21·0	21·5	21·5	21·5	21·3	21·5

Length (cm)				1958				1956–1958
	Feb.	Mar.	May	June	July	Aug.	Total	Total
12·6–13·5	–	–	–	–	–	1	1	25
13·6–14·5	–	–	1	–	–	–	1	60
14·6–15·5	1	2	5	3	2	3	16	89
15·6–16·5	2	–	5	2	2	8	19	215
16·6–17·5	3	2	7	2	2	25	41	390
17·6–18·5	1	1	6	6	3	13	30	475
18·6–19·5	2	–	10	5	7	10	34	698
19·6–20·5	1	3	9	10	13	15	51	1,036
20·6–21·5	1	9	12	6	7	11	46	822
21·6–22·5	–	2	6	3	7	8	26	530
22·6–23·5	3	–	1	1	6	3	14	363
23·6–24·5	–	4	1	–	5	2	12	206
24·6–25·5	1	1	2	2	1	1	8	180
25·6–26·5	–	2	1	–	–	–	3	142
26·6–27·5	1	1	1	–	–	–	3	94
27·6–28·5	1	1	–	–	–	–	2	53
28·6–29·5	–	–	–	–	–	–	–	26
29·6–30·5	–	–	–	–	–	–	–	22
30·6–31·5	–	–	–	–	–	1	1	10
31·6–32·5	–	–	–	–	–	–	–	5
32·6–33·5	–	–	–	–	–	–	–	2
33·6–34·5	–	–	–	–	–	–	–	3
34·6–35·5	–	–	–	–	–	–	–	1
Number of fish	17	28	67	40	55	101	308	5,447
Average length	20·7	22·0	19·9	20·0	21·0	19·5	20·2	21·0

Table 3
Summary of numbers of redfish tagged and recaptured, July 1956—August 1958

Date	Number tagged	Number recaptured	% recaptured
1956			
July	317	203	64·0
August	1,779	918	51·6
September	1,271	397	31·2
November	18	7	38·9
1956 Total	3,385	1,525	45·1
1957			
June	301	75	24·9
July	654	141	21·6
August	585	100	17·1
October	28	0	0·0
November	108	7	6·5
December	78	4	5·1
1957 Total	1,754	327	18·6
1958			
February	17	1	5·9
March	28	6	21·4
May	67	10	15·0
June	40	7	17·5
July	55	0	0·0
August	101	0	0·0
1958 Total	308	24	7·5
Grand Total	5,447	1,876	34·4

port fish were apparently unaffected by temperatures ranging from 34·5°F in February to 55·0°F in August (1·4°–12·8°C). There was a daily summer variation of about 1°F in water temperature, the warmer water flowing from the shallow bays causing the increase at low tide. The difference between surface and bottom temperatures around the docks averaged 0·2°C. A series of bathythermograph casts through the harbour channel to the northern end of Campobello Island showed the water to be nearly isothermal at each station and progressively cooler offshore.

The approximate lethal limits of temperature for redfish were recorded during aquarium studies of fish transported from Eastport to Woods Hole. The fish withstood winter temperatures of 32°F (0°C) without showing distress. As the water cooled further, some died at about 31°F (–0·56°C) and all were killed when the water was chilled to 29·7°F (–1·28°C). During warm weather the temperature ranged between 54° and 58°F (12·2°–14·4°C) for weeks without apparent ill-effects. When it warmed to between 59° and 60°F (15·0°–15·6°C) for 4 days about 10 % of the fish died. All of these temperature changes were very gradual and the fish had some time in which to adjust to the changed conditions.

Summer water temperatures at Eastport apparently were suitable for redfish spawning. Although courtship behaviour or mating activities of adult fish were not observed, gravid females with larvae ready to be released were caught in June and July. Conditions appeared favourable for larval survival. Larvae stripped from gravid fish and placed in jars remained in good condition for hours at harbour water temperature.

Tagging Studies

Number and sizes of fish tagged

Redfish were caught and tagged during each month of the year. Greatest numbers were available in the summer with smaller numbers in spring and autumn and fewest in winter. A summary of tagging operations from July 1956 through August 1958 is shown in Table 1. A total of 5,447 redfish were tagged at four locations on the Eastport Peninsula during that time.

The Eastport redfish averaged approximately 21 cm in length, about 6 cm smaller than those landed from the nearest offshore Gulf of Maine commercial fishing grounds (Fig. 2). The size range of both groups was about the same, but there were comparatively few fish larger than 25 cm caught at Eastport. This difference is partly the result of gear selectivity, hook and line taking many small fish that would escape through the meshes of commercial otter trawls.

There was little seasonal variation in the length composition of the Eastport redfish (Table 2). Few fish smaller than 15 cm or larger than 30 cm were caught, and the mean length of daily samples was consistently between 18·5 and 21·5 cm throughout the year. Greatest differences in length composition were found among fish sampled from different tagging sites within the Eastport area (Fig. 3). The fish tagged at location A were similar in length each year. Fish caught at location B, about 300 yards from A, averaged almost 2·5 cm larger. The small numbers of fish taken at location D, about 3 nautical miles from A, were on average consistently smaller than the fish at the other locations.

Recapture of tagged fish

The successful recapture of about 35 % of all tagged redfish was, in itself, an important result of this study. It showed for the first time that redfish could be tagged and could survive to be recaptured in relatively large numbers. Almost 1,900 tagged fish were recaptured in the vicinity of Eastport, mostly at the tagging site by the investigating party (Table 3). These were measured and returned to the water unharmed, many to be recaptured again, some as often as six times. The length composition of recaptured fish was nearly identical to that of the total tagged population (Fig. 2), indicating that the collecting method was sampling all sizes of fish equally.

The percentage of tagged fish in the population at Eastport reached relatively high proportions in 1958.

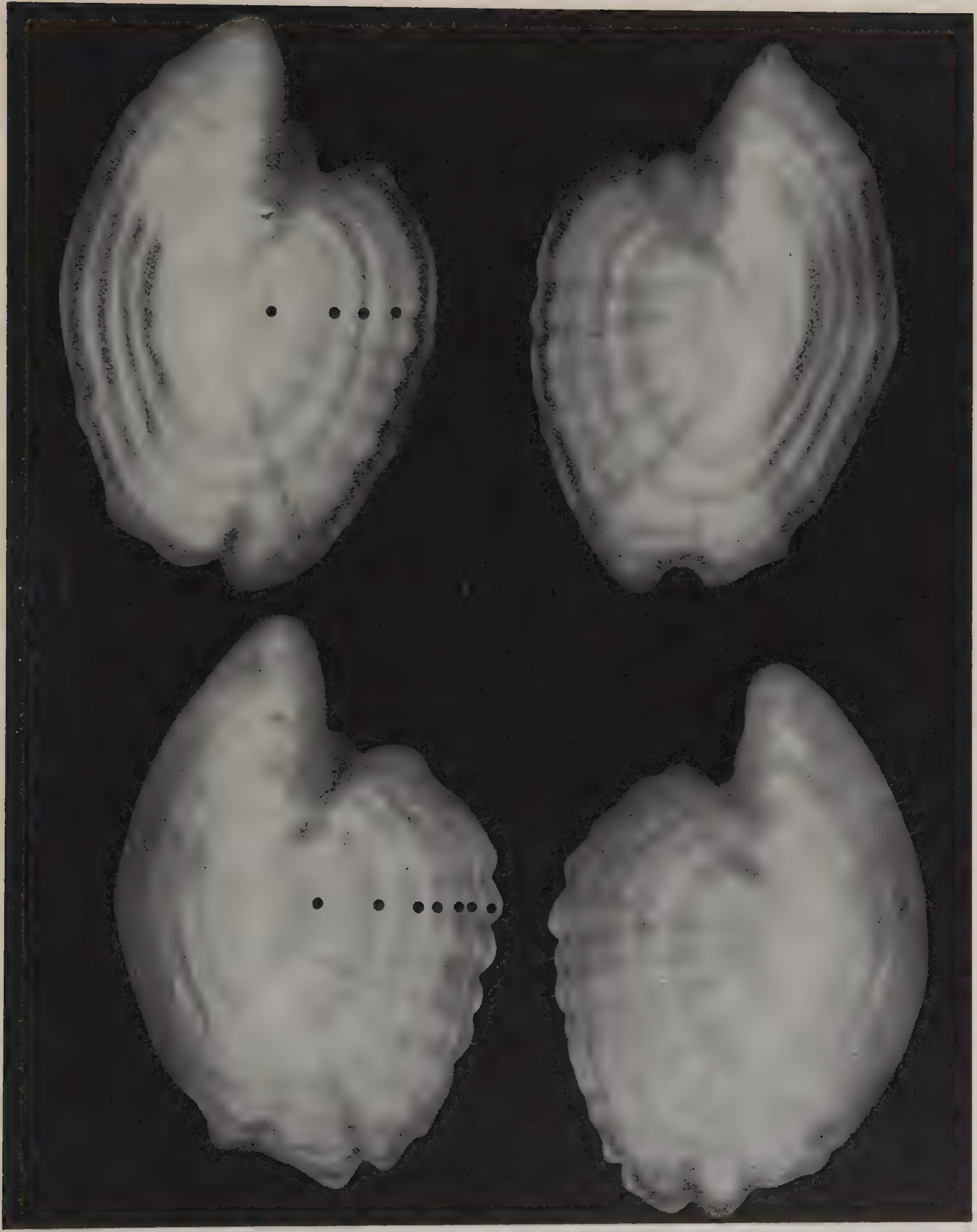

Figure 4. Comparison of otoliths of tagged and untagged redfish caught at Eastport, Maine.
Above – Male tagged 15. September 1956, length 201 mm, age 4 years plus summer growth. Recaptured 16. July 1959, length 205 mm. Wide hyaline zone at otolith edge, typical of tagged redfish otoliths, represents 34 months of diminished growth since tagging.
Below – 209 mm female caught 16. July 1959. Age 7 years plus summer growth. Normal pattern of opaque and hyaline zones is consistent throughout the otolith.

From May through August 1958, between 48 % and 87 % of the fish caught each month had been tagged (Table 1). The highest number of recaptures represented was from groups that had been at large for the longest period of time (Table 3). About 45 % of the 1956 tagging were recaptured, but only 19 % and 8 % respectively, of the 1957 and 1958 taggings have been retaken.

Growth

Preliminary comparisons of lengths at tagging and at recapture of a large number of fish indicated that the measured growth of tagged fish was slower than expected from previous studies of Gulf of Maine redfish (Kelly and Wolf, 1959). Otoliths of tagged redfish were therefore examined for evidence of changes in zone pattern that could be attributed to the effect of tagging. If the growth-rate of the fish was influenced by the tag, the normal growth pattern of the otolith should also be influenced.

Tagging zones in otoliths. In a high percentage of otoliths from tagged fish a large outer zone of hyaline material was present which differed from the obviously banded pattern of opaque and hyaline material in otoliths of untagged fish caught from the same population. The time of formation of this hyaline "tagging zone" appeared to coincide with the time of tagging. The tagging zone usually included traces of one or two thin bands of opaque material (Fig. 4).

To test the ability of the staff to distinguish otoliths from tagged and untagged fish, an unmarked sample of 155 otoliths from tagged and untagged fish was examined. More than 85 % of the otoliths were properly identified as from tagged or untagged fish by two investigators. The tagged fish had been at large for an average of 32 months, and most should have shown three winter growth zones in the otoliths. Otoliths in which tagging zones were mistakenly identified were similar to tagged fish otoliths in having a relatively large amount of hyaline material in the normal growth zones. As mentioned before, it was possible to detect traces of the opaque summer zone, but these traces were seldom clear enough to estimate correctly the number of years at large since tagging. Estimates of this sort were almost always short of the actual period of time that the fish had been tagged.

Calculated growth. Age readings of otoliths show the growth-rate of untagged fish to be approximately equal to that of tagged fish prior to the time of tagging (Figure 5). Age was read to the beginning of the tagging zone in the tagged fish otoliths and was plotted against fish length recorded at the time of tagging. Average growth of males and females in both groups was between 14·5 mm and 20·1 mm per year. The change from the normal year zone pattern in otoliths to the primarily hyaline pattern of the tagging zone suggested that after tagging growth was reduced to a very low level.

Table 4

Approximate annual length increment of tagged and untagged redfish 15 to 25 cm in length

Area	Males (mm)	Females (mm)
Eastport – Tagged	1·0	1·0
Untagged	14·5	20·1
Offshore Gulf of Maine – Untagged	20·0	24·2

Measured growth of tagged fish. The measured growth of tagged fish during the period of tagging was extremely slow. The deviations of lengths at recapture from the original tagging lengths of more than 2,500 fish are plotted in Figure 6. A regression line fitted to these deviations shows an average growth of 1 mm in a year. That this value is a small fraction of the average annual growth increment calculated for Gulf of Maine redfish is shown in Table 4.

Evidence of the slow growth during tagging is shown in more detail by the repeated measurements of fish that were recaptured and released several times (Table 5). Most of the fish grew less than 8 mm during almost two years of freedom in natural environments.

Effect of tagging on growth-rate. The great difference in growth-rate of tagged and untagged fish suggests that tagging has somehow altered the normal growth pattern of the tagged fish. The apparent effect of tagging on the growth-rate of each year-class is shown diagrammatically in Figure 7. Age readings from otoliths of tagged fish were combined with information on the lengths at tagging and recapture to obtain the average length of each year-class at tagging and at recapture. The decrease in growth-rate after tagging for all ages is dramatic. Although the young fish appear to grow slightly faster than the older ones, the growth-rates of the separate age-groups were generally less than 4 mm per year during the 3-year period of tagging.

It is impossible to say at this time how the growth of the fish is affected by tagging. Tagged fish appeared normal and healthy, apparently feeding on natural food and biting readily on cut bait. Although the tag interferes in no obvious manner with the movement of the fish's mouth, perhaps it serves to startle live prey, causing it to escape. This would reduce the quantity of live food captured and would in turn influence the growth-rate. Such starvation would probably increase the willingness of the tagged fish to take cut bait and could account for the extremely high proportions of tagged fish (85 %) that were frequently recaptured.

Summary of growth. All evidence indicates an abnormally decreased growth-rate of the tagged fish.

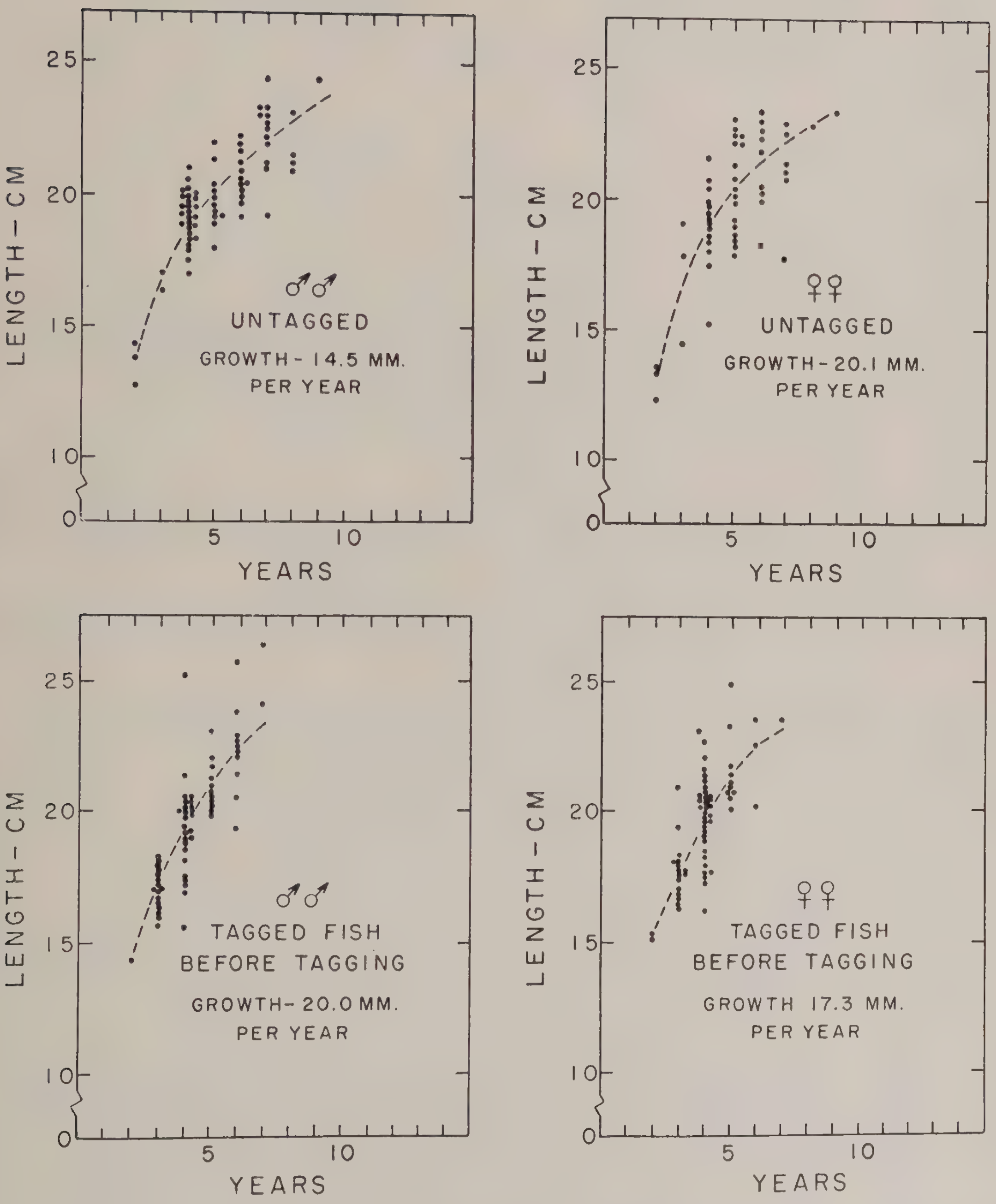

Figure 5. Growth-rates of untagged redfish and tagged redfish prior to the time of tagging. Based on otolith readings.

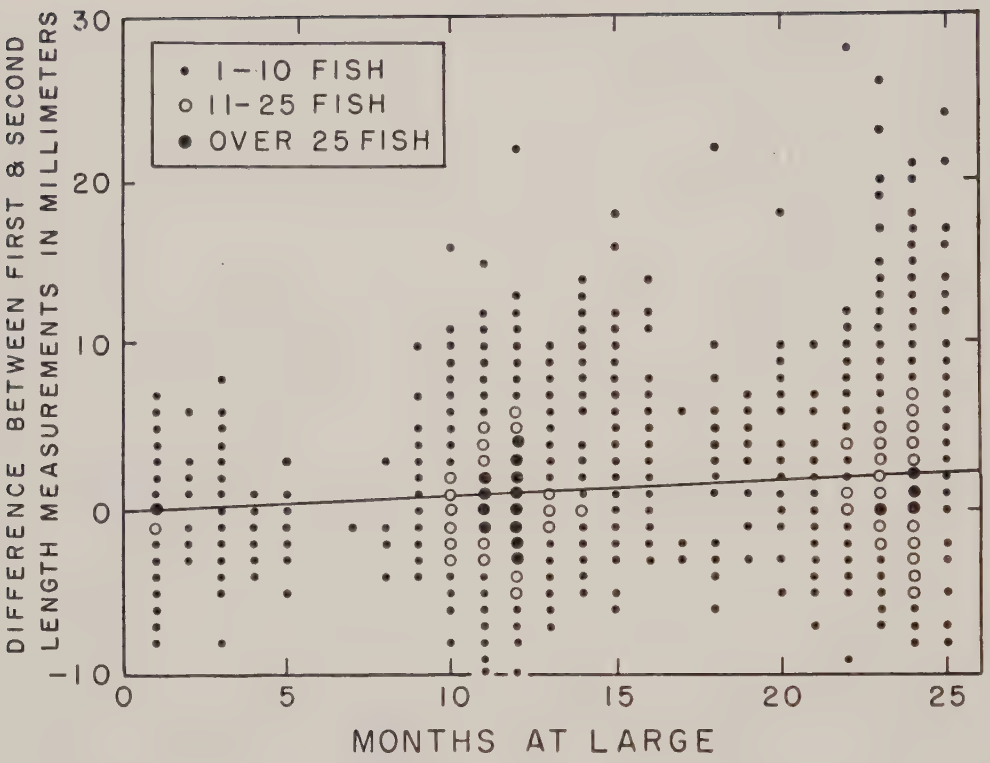

Figure 6. Regression line fitted to positive and negative growth increments of 2,365 recaptured fish (b = 0·08284).

Table 5

Length measurements of redfish recaptured four or more times

Length at tagging (mm)	1st Recapture		2nd Recapture		3rd Recapture		4th Recapture		5th Recapture		6th Recapture	
	Months at large	Length	Months at large	Length	Months at large	Length	Months at large	Length	Months at large	Length	Months at large	Length
157	11	156	21	155	23	157	23	156	–	–	–	–
160	11	160	21	159	22	160	23	160	–	–	–	–
161	11	157	21	168	22	168	23	168	–	–	–	–
165	10	166	13	163	22	165	23	165	–	–	–	–
169	12	171	15	172	24	170	25	172	–	–	–	–
175	13	176	14	179	21	179	23	184	–	–	–	–
176	11	173	12	173	21	174	23	175	–	–	–	–
188	1	183	10	190	12	189	24	196	–	–	–	–
193	12	192	12	191	22	192	23	193	–	–	–	–
195	10	202	12	204	16	209	25	205	–	–	–	–
195	13	195	20	196	25	200	25	200	–	–	–	–
198	2	200	12	203	13	202	22	202	23	205	–	–
198	10	202	15	205	23	205	24	200	–	–	–	–
198	11	203	12	202	23	201	24	202	–	–	–	–
202	2	202	13	202	24	203	25	203	–	–	–	–
202	12	205	13	200	24	203	25	200	–	–	–	–
202	11	203	12	204	13	202	16	205	24	207	–	–
203	12	205	13	204	16	208	24	210	–	–	–	–
205	1	203	11	205	12	203	24	205	–	–	–	–
209	2	206	11	209	12	215	16	213	–	–	–	–
213	1	210	3	214	12	221	15	229	–	–	–	–
223	12	220	13	225	23	222	24	223	–	–	–	–
228	12	220	15	225	23	222	25	221	–	–	–	–
251	1	248	12	244	21	248	24	250	–	–	–	–
252	12	252	15	252	19	256	24	255	25	255	–	–
254	1	256	11	258	12	254	22	263	23	254	24	256

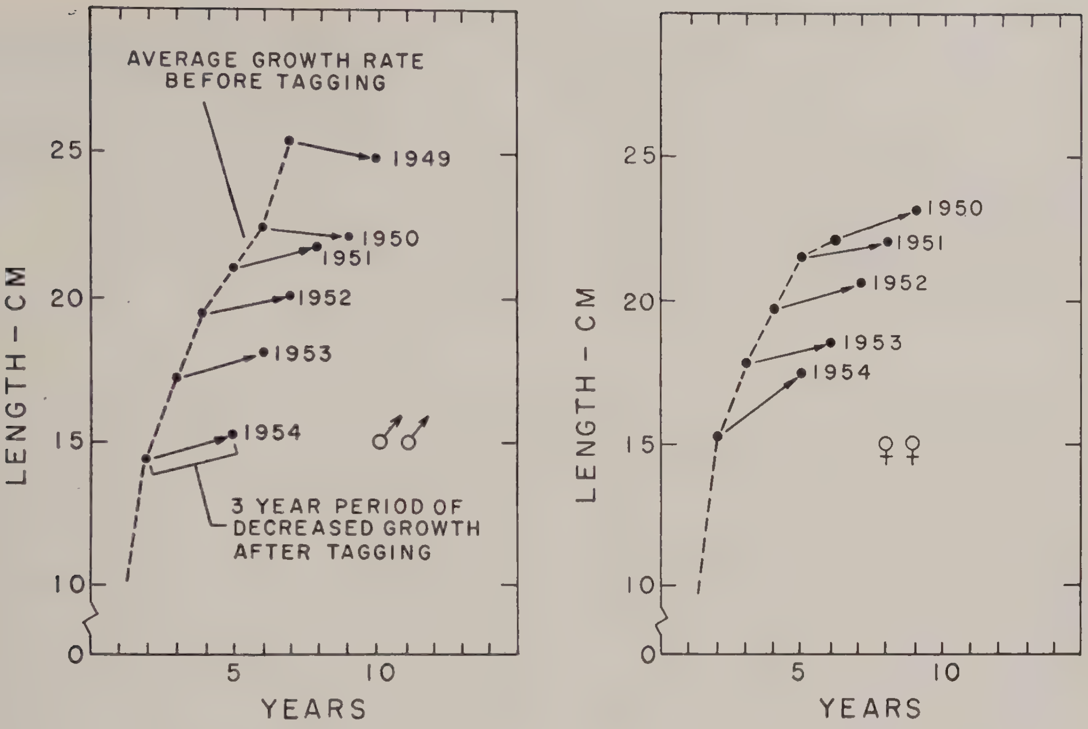

Figure 7. Apparent effect of tagging on growth-rate of separate year-classes during 3-year period of tagging.

Table 6

Numbers of different fish recaptured one or more times (Cumulative totals in parentheses)

Year	Number of fish tagged	Number of different fish recaptured	Total number of recaptures	Number of times recaptured through August 1958: 1	2	3	4	5	6
1956	3,385	1,525		1,041	349	109	20	5	1
			(2,177)	(1,525)	(484)	(135)	(26)	(6)	(1)
1957	1,754	327		277	44	6	–	–	–
			(383)	(327)	(50)	(6)	–	–	–
1958	308	24		23	1	–	–	–	–
			(25)	(24)	(1)	–	–	–	–
Totals	5,447	1,876		1,341	394	115	20	5	1
			(2,585)	(1,876)	(535)	(141)	(26)	(6)	(1)

Table 7

Total number of fish tagged with number and percentage recaptured through August 1958. Arranged by location of tagging and recapture to indicate degree of intermixing

Tagging locations	Total number of fish tagged	recaptured	% recaptured	Numbers and % recaptured at A	B	C	D
A – Steamer Dock	4,047	1,563		1,557	6	0	0
			38·8	(38·6)	(0·2)		
B – Wadsworth's Dock	562	70		2	68	0	0
			12·5	(0·4)	(12·1)		
C – Kinney's Mooring	505	223		223	0	0	0
			44·2	(44·2)			
D – Deep Cove	333	20		0	0	0	20
			6·0				(6·0)

First, tagging had a visible effect on the growth pattern of the otoliths, suggesting that the physiology of the fish was definitely influenced by tagging. Second, the growth-rate obtained from otolith readings indicated that before tagging the tagged fish had grown at the same rate as untagged fish but that after tagging they grew more slowly. Finally, measurements of tagged fish show growth to be so slow that it is not in accord with the growth-rate of the untagged fish nor with the apparent growth-rate of the tagged fish in the years prior to tagging.

Migration

Redfish are found at Eastport throughout the year, and these studies indicate that they do not migrate away from the area. The number of fish observed or caught at the tagging site varied seasonally, however. This was probably caused by the response of the fish to seasonal changes in water temperature. Comparatively few fish were caught in the winter although considerable numbers were sometimes seen at the docks. As spring approached, greater numbers of both tagged and untagged fish appeared. Large numbers were usually present at night throughout summer and autumn. About 35 % of the tagged fish were recaptured at or near the tagging site (Table 1). There were no recaptures from any other location.

The repeated recapture of the same fish during a span of two years is perhaps the most remarkable aspect of the present study. Almost 400 fish were recaptured twice and one six times (Table 6). Such unexpected results in an open marine environment suggest that the fish are strongly attracted to particular home grounds.

Within the Eastport region, redfish showed little evidence of movement over distances of half a mile or less (Fig. 1 and Table 7). Fish tagged and released at locations A, B, and D were mainly recaptured at the same place. Each of these three locations was at the edge of deep water where redfish frequently appeared. A homing tendency was shown by fish removed from their home grounds, A, and released in a new location, C. Location C was a sheltered mooring in shallow water used only during bad weather. The movement from C to A of approximately two-thirds of a mile was the only clear example of concerted travel between areas. In this instance it was natural for the fish to seek deep water when released. This suggests that although the fish show little normal tendency to move, they will travel some distance when removed from their normal habitat.

Table 8

Population estimates based on numbers of tagged fish released and recaptured at Eastport

Date	Total number of		Number of tagged fish recaptured	Estimated population
	fish captured	tagged fish available		
Sept. 1956	1,202	1,685	153	15,289
Nov. 1956	102	2,734	25	14,733
July 1957	644	2,803	270	9,573
Nov. 1957	335	3,676	162	7,955
June 1958	166	3,974	125	7,781
Aug. 1958	795	4,014	694	6,498

The most unusual aspect of the local migration pattern was the comparative lack of intermixing of the two tagged groups between locations A and B. The two points are about 300 yards apart with no physical or hydrographic barriers between. The current sweeping along the shore can traverse the distance from B to A in less than 5 minutes. The situation would seem to dictate the complete mixing of the two groups. Despite these conditions, only 0·2 and 0·4 % respectively, of the A and B taggings have been recaptured at the adjoining location (Table 7). In July and August 1958, although 85 % of the fish caught at A were tagged, virtually none of the tagged fish were from location B.

Population estimates

The behaviour of the Eastport redfish makes it difficult to estimate the size of the total population with a high degree of accuracy. The tendency for some of the fish to appear or to remain only at the steamer dock (location A, Fig. 1) results in an unusually large number of recaptures from a very small part of the total area of the harbour. The repeated recapture of a small number of the tagged fish introduces bias which gives a low estimate of the total number of fish. Estimates of the population at the steamer dock based on the procedures developed by Schnabel (1938) and Ricker (1948) range from 15,289 fish in September 1956 to the latest figure of 6,498 fish in August 1958 (Table 8). The authors' own observations would lead to the estimate that this population numbered at least 10,000 individuals, possibly more than 20,000.

Conclusions

Behaviour

The daily routine of Eastport redfish is influenced by the cycles of light intensity and tidal movement. The fish remain inactive on the bottom or in dark, rocky crevices during the day, becoming active at night. They feed mainly at night, moving toward the surface in search of food. Similar movements on the offshore grounds would cause a nocturnal reduction in redfish availability to the otter trawl, a condition that is typical of the commercial fishery in the Gulf of Maine.

Redfish generally appear to avoid swift currents and are very scarce at the docks as the "spring" tides of the monthly cycle begin. They respond seasonally to temperature, becoming inactive when the water cools below 40°F (4·4°C). Apparently the range from approximately 40° to 55°F (4·4°–12·8°C) is optimal for Eastport redfish.

Migration

The diurnal cycle of feeding results in a very local vertical migration within the area. Redfish will travel short distances when necessary, and they may be capable of homing to a chosen locality. There is no indication that they perform extensive migrations. Their sedentary behaviour suggests that long-distance travel, if undertaken, is a slow movement into new feeding grounds over a long period, rather than a cyclic movement to and from an area.

The Eastport population probably originated in the deep water of the Gulf of Maine, moving into the area through the deep channel north of Campobello Island. Living in the shallow water of the region, they are able to rise to the surface to feed on the abundant euphausiid shrimp. The apparent effect of living in the bright illumination near the surface has been to make the fish darker than the offshore group.

Growth

The normal growth-rate of Eastport redfish is slightly lower than that of the offshore Gulf of Maine fish. Growth of tagged fish is much slower than the normal growth of the Eastport fish. The lowered growth-rate appears to be due to some inhibiting influence of the tag.

Tagging has not validated the growth-rates obtained from previous Gulf of Maine studies. The annual length increment of tagged fish was only a fraction of the amount predicted in even the lowest computed growth-rate. Nonetheless, these results are suggestive evidence against the probability of fast growth within the Gulf of Maine redfish populations.

Acknowledgements

The success of tagging operations at Eastport was in part due to the co-operation of the local people. We are particularly indebted to Captain Oscar Kinney, Captain Karl Brooks, and Mr. Sheldon Trott, Jr., for their aid and the use of their equipment. We wish also to acknowledge the efforts of Messrs. Kenneth Allen, Claude F. Bocken, George M. Clarke, Franklin D. Roberts, and Walter T. Pereyra for their assistance.

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A Contribution to the Problem of the Age Determination and Growth-Rate in *Sebastes*

By

E. J. SANDEMAN
Fisheries Research Board of Canada
Biological Station, St. John's, Newfoundland

Introduction

Growth studies on redfish (*Sebastes marinus* L.) have been reported by several workers both in Europe (Smaragdova, 1936; Veshchezerov, 1944; Kotthaus, 1949, 1952, 1958; Travin, 1951; Bratberg, 1956; Rasmussen, 1958) and in North America (Perlmutter and Clarke, 1949; Anon., 1957; Steele, 1957; Marty, 1958; Kelly and Wolf, 1959; and Sandeman, 1957, 1958). The integration of these data on growth-rates into an overall picture of *Sebastes*, its distribution and biology, is somewhat complicated by the lack of agreement on the taxonomic status of the different "types" of redfish reported as occurring over almost its complete geographic range. This problem is particularly difficult since the maximum sizes attained and the growth-rate appear to be considerably greater for *marinus*-type than for *mentella*-type redfish (Travin, 1951). (The literature on, and the distribution of the different "types" of *Sebastes* is discussed by Templeman, 1959.)

In spite of the difference in growth-rates between the two major "types" of *Sebastes*, and the differences in growth-rates that may be expected in stocks of the one "type" in different geographical locations and different depths, there is still a very wide underlying divergence in age determination apparent within the same population, and even within the same group of otoliths, when examined by different workers. Some workers (Kotthaus, 1949, 1952, and 1958) have come to the conclusion that the growth-rate is relatively fast, whereas the majority of other workers have concluded that it is remarkably slow. The problem was discussed at the ICNAF Symposium held in Biarritz, France in March 1956, and the general opinion was that the wide divergence in growth-rates obtained by adherents to these two schools of thought was, for the most part, due to basic differences in the method of interpreting the zones of the otoliths.

The evidence presented here amplifies data reported at the meeting referred to above (Sandeman, 1958), and supports the general conclusion of a slow growth-rate in *Sebastes*.

Hermitage Bay and its Redfish

The fish used in this study were all obtained by otter trawling in Hermitage Bay on the south coast of Newfoundland (Fig. 1). This bay is funnel shaped, about 7 miles wide at the mouth with the outer part narrowing down over the course of some 13 miles to a width of 1 mile. From there it continues inland as a narrow cleft varying in width from ¾ to 1½ miles before finally terminating a further 11 miles inland. The edges of the bay are steep, and deep water (200 m) extends over most of the area to very close inshore. Redfish may be caught over the entire deep-water area and, even after the bay narrows to a width of 1 mile, catches of 3,000–4,000 pounds (1,360–1,820 kg) of redfish per 30-minute haul have been obtained only 2 miles from the head of the bay.

Hermitage Bay is apparently well suited to redfish, and in the two years before the bay was closed to the larger trawlers (at the Confederation of Newfoundland with Canada in 1949) over 7 million pounds of redfish were taken from the outer part and just outside the bay. There is no shallow bar at the mouth and, although the temperatures of the surface and intermediate layers of water are subject to considerable seasonal variation, the temperature of the bottom water has remained within rather narrow limits, and at depths between 250 and 300 m has varied only between 4·5°

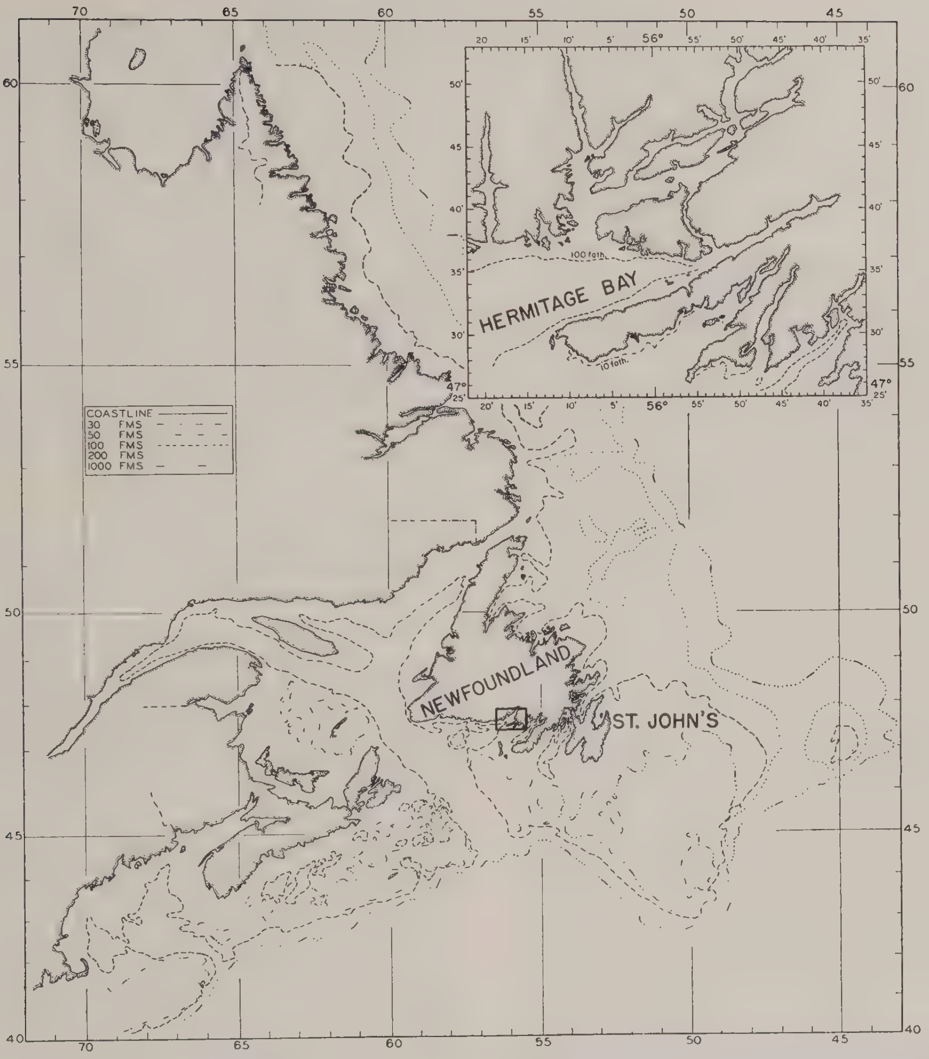

Figure 1. Chart of Newfoundland area showing location of Hermitage Bay.

and 6·0°C during the six years for which detailed hydrographic data have been obtained.

Almost all the hauls were made in a rather restricted area of about 3 square miles in the depth range 130–145 fathoms (238–265 m). A few hauls outside this area, but still within an area of about 14 square miles and in the depth range 120–180 fathoms (220–330 m), have also been included. The variation in the catches between the extremes of the depth range may be considerable, both in catch per unit of effort and in length-frequency distribution, but in this examination of age and growth it is considered that this variation is of little importance.

In the area where most hauls were taken and where the depth range was 130–145 fathoms (238–265 m), the fish are almost entirely of the typical *mentella* type. This is illustrated by the fact that in some 170 hauls which were made in this area during the year 1958, only 36 *marinus*-type fish were taken as compared with over 147,000 *mentella*-type fish. In depths at the shallow end of the complete depth range and over a more rocky bottom, *marinus*-type fish were found to be slightly more plentiful, but were still far outnumbered by the usual typical *mentella* form. Therefore, it is suggested that the rate of growth reported here may be regarded as a preliminary estimation of that of the North American *mentella*-type redfish from an area on the south coast of Newfoundland.

Growth-Rate of Juvenile Fishes

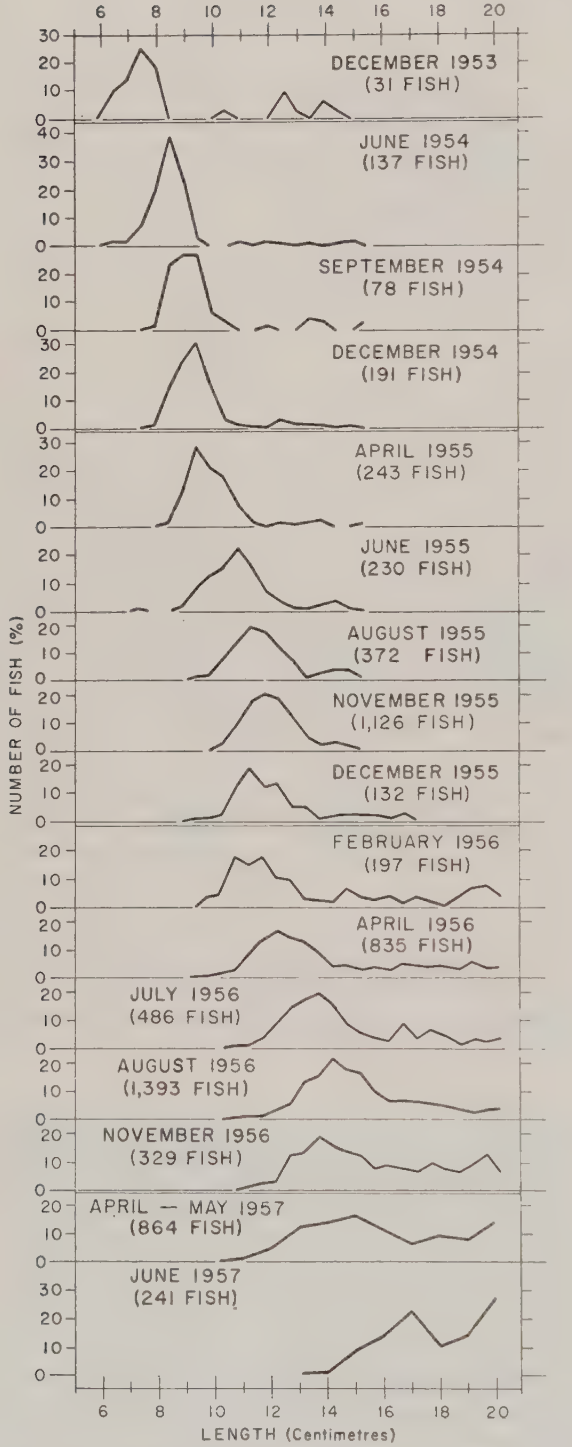

Figure 2. Length-frequency polygons of small redfish (sexes combined), caught in Hermitage Bay, 1953–1957.

Examination of length-frequencies (Petersen's method)

Hansen (1957, 1958 a, b, and c, and 1959) has reported a very interesting series of length measurements of small redfish from Godthåb and Tunugdliarfik Fjords taken during various months of the year from 1952–1957. These measurements illustrate the progression of the modes of different year-classes, and allow an estimation of the growth-rate during the early years of the life of the fish. These data show an extremely slow rate of growth.

A similar series of length measurements of small redfish taken in Hermitage Bay during various months of the year from December 1953 to November 1955 has been reported by Sandeman (1957, 1958), and this series has been continued in somewhat less detail during the period 1956–1959.

The small fish were caught by means of a No. 35 or 35A* otter trawl, the cod-end of which was lined or covered with either $^{1}/_{2}$ inch mesh nylon or $^{3}/_{8}$ inch mesh cotton netting.

The length-frequency polygons (sexes combined) of the small redfish obtained during trips to Hermitage Bay, 1953–1957, are displayed in Figure 2. All lengths reported here are "fork lengths", the measurements being taken from the anterior tip of the lower jaw, with the mouth closed, to the end of the median caudal rays.

During the years 1953, 1954, and 1955, all redfish with lengths of 15 cm and under were separated from the catch and measured to the nearest mm. In Figure 2 the measurements have been combined in 0·5 cm groups and the numbers of fish occurring in each 0·5 cm group have been expressed as percentages of the total number of fish 15 cm and under. In 1956 all fish with lengths of 20 cm and under were separated from the catch and measured in 0·5 cm groups. The measurements have been plotted in 0·5 cm groups, and the numbers of fish in each 0·5 cm group have been expressed as percentages of the total number of fish 20 cm and under. In 1957 no special attempt was made to separate the small fish, and they were measured to the nearest cm as they occurred in the complete catches or in random samples of the complete catches. In Figure 2 the 1957 data have been plotted in cm groups and are expressed as percentages of the total number of fish 20 cm and under.

The progression of the modes from December 1953, through the subsequent months and years to 1956 can clearly be observed in Figure 2. This is particularly so, since the dominant group represents a single year-class well separated from the remainder of the fish in the catch, due to relative failures of year-classes, both before and after it. In 1957 this dominant group of small redfish cannot be so easily discerned and by 1958 and 1959 it had, to a great extent, lost its identity, having started to merge with the peak above it. During these latter two years the group can no longer be isolated, and must be examined in relation to the length-frequency of the complete catch.

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* The No. 35A otter trawl is a modified No. 35 trawl, but in both nets the width of the mouth of the net is the same, the headline having a length of 50 ft (15·25 m).

Figure 3 shows the length-frequency polygons of the complete catch in terms of numbers of fish caught per hour at each cm group during selected trips for the years 1954–1959. The catch per hour is based on the catches of a No. 35 or No. 35A net having the cod-end covered with $^1/_2$ inch nylon or $^3/_8$ inch cotton netting. The trips have been selected to be representative of that period of the seasonal cycle when largest catches are to be expected in the area (June to September). The merging of the group of small fish in Figure 2 in the peak above it can be observed, and it appears that this group is exerting a considerable influence on the fish which make up this peak.

Growth-rate from scales and otoliths

Although many workers have used the otolith or scale method, or both, for estimating the ages of redfish, few have had good opportunities for checking the validity of the method used. Because the divergence of opinion between those who favour a slow growth-rate and those who favour a fast growth-rate is due, most likely, to the different methods of age estimation, the establishment of the validity of the method used becomes of the utmost importance.

Perlmutter and Clarke (1949), after examining the scales of redfish obtained during various months of the year from the Gulf of Maine, have shown that, in a single year, the scales reveal but a single zone of widely spaced circuli followed, during the period November through March, by a zone of narrowly spaced circuli.

North American biologists have also found that for redfish of the Gulf of Maine (Anon., 1957; Kelly, 1958; Kelly and Wolf, 1959) growth of the otoliths shows but a single pair of opaque and hyaline zones to be formed during a single year.

Bratberg (1956) has shown, by examination of the otoliths from samples taken from a stock of juvenile fish at various intervals throughout a period of over a year, that one opaque and one hyaline zone constitute an annual ring, and that the edges of the scales were found to correspond to this, a single band of broadly spaced circuli followed by a single band of narrowly spaced circuli making the scale growth for a single year.

The group of small redfish, which has been followed for several years in Hermitage Bay, Newfoundland, has also revealed that, during a single year, scale growth shows only the formation of a single band of widely spaced circuli followed by a single zone of narrowly spaced circuli (Sandeman, 1958). This group of fish has now been followed for six years, and although it becomes rather difficult to distinguish between the zones of the scales after the fish are about 4 years old, the otoliths have remained relatively clear, and in each successive year a further pair of zones, a hyaline and an opaque, can be observed to have been laid down. The duration of the period in which the different zones are formed is somewhat variable, apparently depending on the characteristics of the water and food during the different years, but in general the opaque zone of an otolith is laid down between April–May–June to September–October–November, and the hyaline zone from September–October–November to about April–May–June.

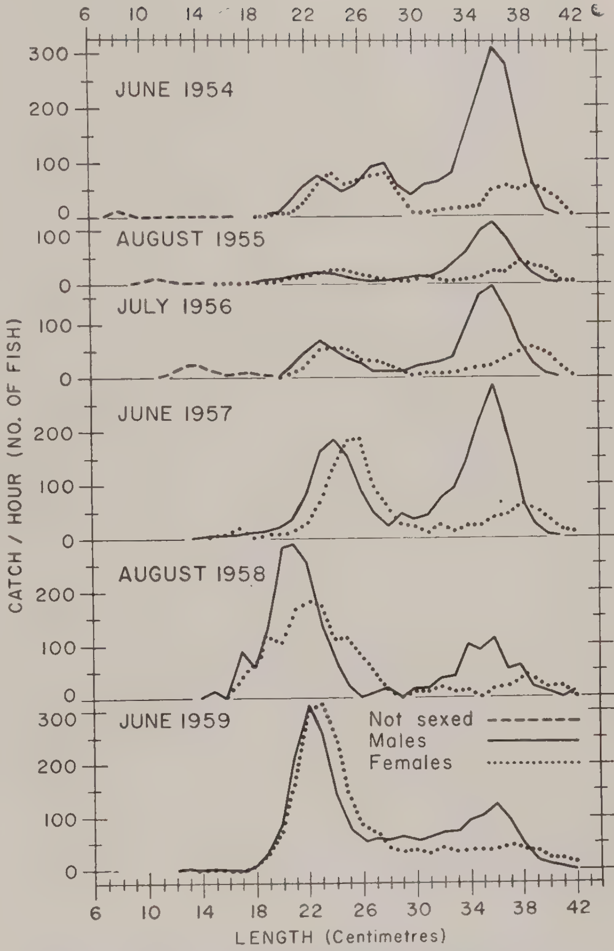

Figure 3. Length-frequency polygons of all redfish caught during trips to Hermitage Bay, 1954–1959.

Ages of the small redfish from Hermitage Bay

The small redfish in Hermitage Bay first appear on the bottom during the winter months when they are about 60–80 mm in length. It is perhaps worthy of comment that at this time of the year the water column is almost uniform in temperature from top to bottom, and the characteristic cold water intermediate layer (–1·0 to 0·0°C), which is always present throughout the remainder of the year to a greater or lesser extent, has been dissipated.

During this winter in which they first make their appearance on the bottom, the first indications of a definite hyaline zone of the otolith and the first zone of narrowly spaced circuli on the scales may be observed. It is not known, however, whether or not this first zone of narrowly spaced circuli of the scales and the first definite and clear hyaline zone of the otoliths really represent the first "winter" of the fish, and whether the extensive growth from 7–8 mm in May–June, when the larvae are extruded, to 60–80 mm in December takes place during the first year of life of the fish, or whether the pelagic period of its post-larval life extends over a period greater than a year. There are some indications from Hermitage Bay that the fish may actually be in their second year of life when they settle on the bottom, but, in view of the paucity of this evidence and the evidence of Kelly (1958) and Kelly and Wolf (1959) that the young redfish in the Gulf of Maine attain a length of about 50 mm by December of their first year, it is better to leave the issue undecided until more adequate samples of pre-settled small fish have been collected from the Hermitage Bay region itself.

Whether the fish are in their first year of life or older at the time of formation of the first hyaline zone of the otoliths or the first zone of narrowly spaced circuli of the scales does not affect the use of otoliths and scales for the determination of age, and provided the age determination is consistently referred to the easily distinguishable first definite hyaline zone of the otolith and the equivalent first zone of narrowly spaced circuli of the scales, the determination of age from otoliths and scales may proceed.

All the ages used in this paper are referred to the first definite hyaline zone of the otoliths and the corresponding first zone of narrowly spaced circuli of the scales as being the first "winter" zone of the fish's life. The end of each zone of "winter" growth is coincident with the "birth date" of the fishes and thus a straight count of the number of complete "winter" zones provides the estimate of age. Because so little growth takes place during the months January–May, it is convenient to regard the birth date as in January so as to put the estimated ages on a calendar year basis.

In the years 1953–1957, random samples, usually of about 150 fish, were obtained from the small redfish during each trip to Hermitage Bay. These fish were usually measured to the nearest mm before being preserved in 95 % ethyl alcohol for later examination at the laboratory. The scales and otoliths were subsequently removed and preserved in vials containing 95 % ethyl alcohol.

For age reading the scales were cleaned in a solution of sodium peroxide and mounted in a gum-arabic solution on a glass slide under a coverslip. As only very occasional otoliths were "clear" enough to be read whole, all otoliths were cracked transversely before being examined under a binocular microscope (13×). The cracked surface of the otolith, moistened with 95% ethyl alcohol or immersion oil, was usually viewed

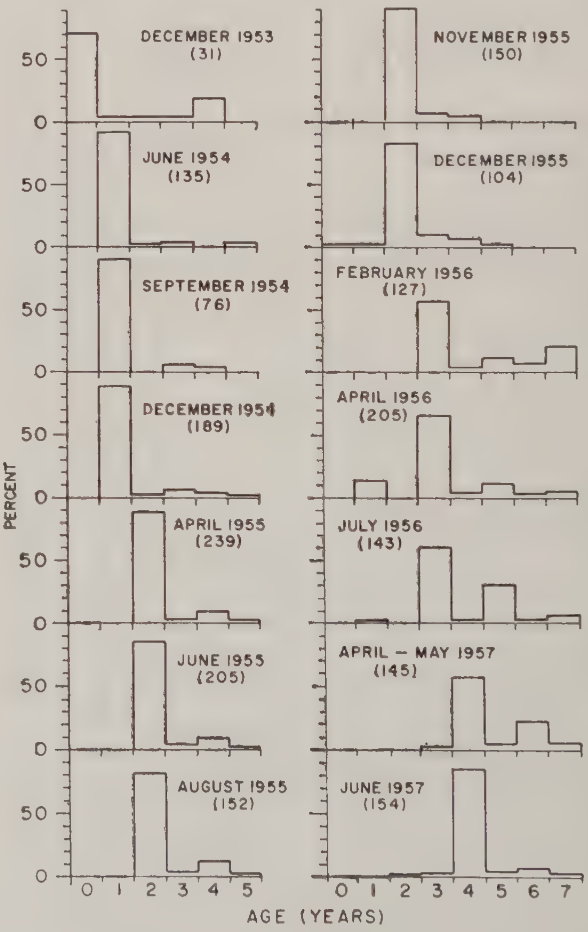

Figure 4. Age-frequency histograms corresponding to the length-frequency polygons shown in Figure 2. The figures in parenthesis indicate the number of fish, the otoliths of which were examined for age determination.

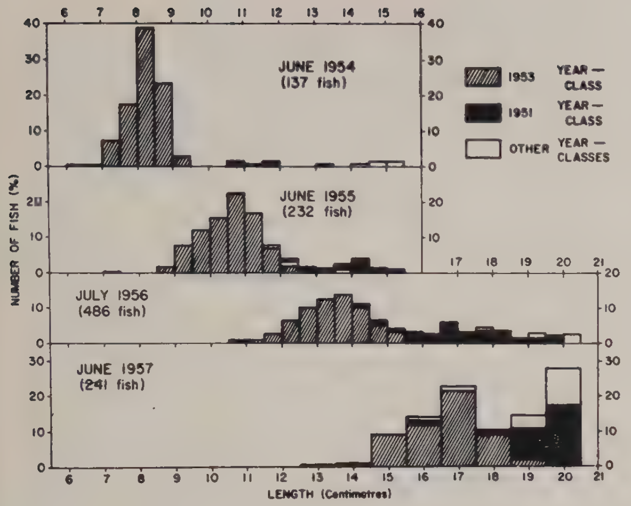

Figure 5. Length-frequencies shown in Figure 2 for June or July 1954–1957, broken down to show year-class composition at each length group.

by reflected light, with all the otolith surface, other than the cracked surface, shielded from the light.

For the younger fish (to about 4 years of age) the otoliths and scales were read independently, and the few age estimations which did not agree were re-read and argued to best agreement. In the older fish of the series no recourse was made to the scales, and two independent age estimations from the otoliths served the same function.

Age-frequencies, corresponding to the length-frequencies in Figure 2, are shown in Figure 4. These have been expressed as percentages of the number of fish, 15 cm and under, occurring in the sample during 1953, 1954, and 1955, and percentages of the number of fish 20 cm and under, during 1956 and 1957.

These age-frequencies emphasize the fact that the group of small fish is made up of a single year-class which, for several years, dominates the year-classes both above and below it, and that during the four years following the settlement of this dominant year-class, only very few fish of more recent year-classes have succeeded in settling to the bottom in this area.

The dominance of the 1953 year-class can be more clearly seen in Figure 5 where the length-frequencies shown in Figure 2 for June or July 1954–1957, have been broken down to show year-class composition at each length group. The length-frequencies are presented as histograms and for the sake of clarity only the 1951 and 1953 year-classes are shown separately, all other year-classes being combined together. The dominance of the 1953 year-class is quite striking.

The mean lengths of the fish of this dominant year-class have been calculated at each time of sampling, and Figure 6 indicates the rate of growth of this single year-class. The mean lengths were calculated for most samples from measurements made before preservation in ethyl alcohol. For a few samples, only measurements made after preservation were available, and in these cases the mean lengths of fish after preservation have been converted to mean lengths of fish when fresh. During 1954, 1955, and 1956 sufficient samples were obtained at different seasons of the year to illustrate the seasonal growth cycle, but in the more recent years adequate sampling of the year-class by nets with fine meshed covers has been restricted to but one or two trips, and the seasonal cycle cannot be recognized.

A comparison of the growth-rate shown by the 1953 year-class with that determined from ages derived from other year-classes, and from samples in which no upper limit for selection of fish was used, indicates that the 1953 year-class has shown unusually fast growth.

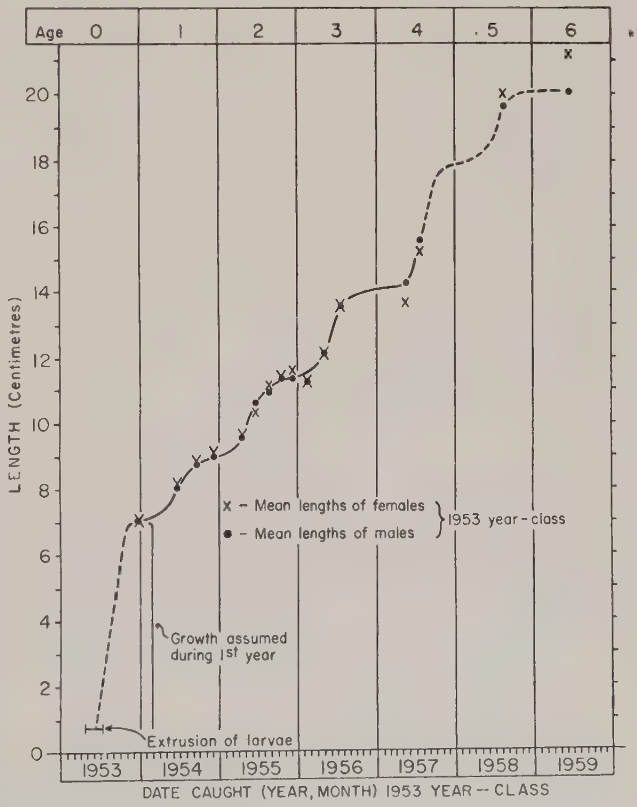

Figure 6. Growth of the group of young fish (1953 year-class) in Hermitage Bay, as shown by the mean size of the year-class at time of catching. Only the curve for males has been drawn.

Growth-Rate of the Larger Fish

Examination of length-frequencies

The length-frequency distribution of the fish in Hermitage Bay, as observed during the years 1954–1959, is characteristically tri-modal (Fig. 3). In addition to the group of young fish, tentatively regarded as the 1953 year-class, a second group, having a mode at 22–23 cm for males and 24–26 cm for females has shown up consistently during the years 1954–1957. The other peak, which for males is well defined at 36 cm, is not so clear for the females but can usually be recognized at 38–40 cm. A further peak, intermediate in position to the two already mentioned, occurs occasionally. (It may be seen in the length-frequency polygon shown for 1954 in Fig. 3.) The sporadic occurrence of this peak continues to be perplexing, particularly as its appearance and disappearance may occur over a very short period of time.

It has been shown that, for the juvenile fish, the progression of the modes of the length-frequency polygons, although rather slow, is easily discernible, particularly when consecutive years are considered. An examination of the length-frequency polygons for all sizes of fish in the catch (Fig. 3) does not reveal any easily discernible progression of the two major peaks of the large fish during the six years for which data are shown. Some progression can be seen in the lower of these two peaks (males at 22–23 cm and females at 24–26 cm) during the years 1954–1957, but in 1958 and 1959 this progression is disturbed by the merging of the 1953 year-class with this group. The peak for large males, which is particularly well defined, has remained at 36 cm for the six years shown, and indeed also appears at the same length group during catches in 1947 and 1948. The corresponding peak for females, although not so clear, also appears to have remained stationary for many years.

The very slight progression of the peak with modal lengths of 22–23 cm for males and 24–26 cm for females and the complete lack of movement of the peak for the large fish are suggestive of a very slow growth-rate, with the oldest fish attaining a final size, after which no further measurable growth in length ensues. The relative immobility of the latter peak is interpreted as due to the combined effect of the practically negligible growth that would occur in the fish of considerable age and the piling up of a number of year-classes within the single peak.

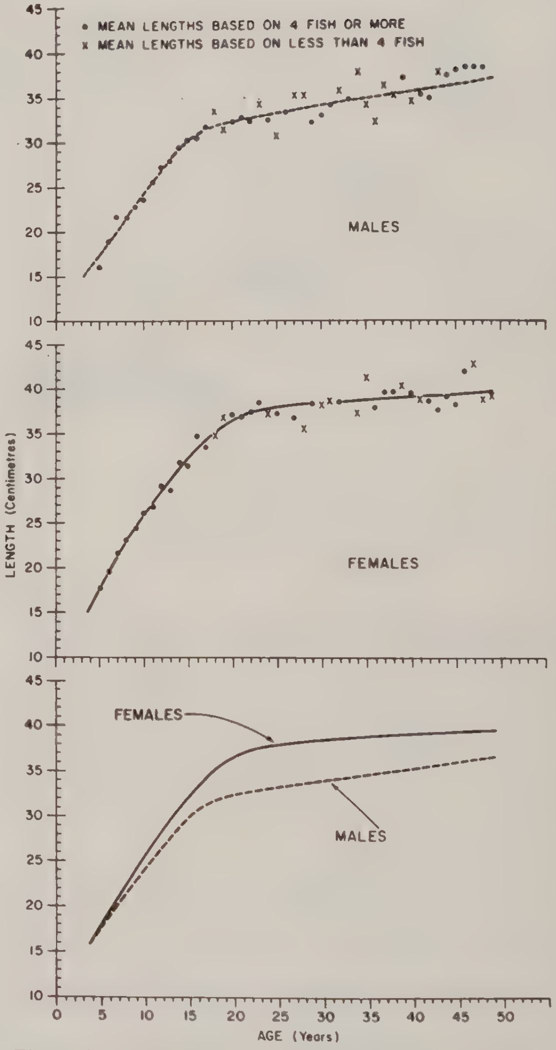

Figure 7. Growth curve of redfish from Hermitage Bay.

Age estimation and growth-rate from otoliths

Although during the early part of the fish's life, there is considerable evidence that the annual pattern of otolith growth consists of the formation of a single pair of zones (one hyaline and one opaque), this definite evidence is lacking for the older fish. To extrapolate this principle to fish which are older, and in most cases sexually mature, is perhaps to invite criticism, but in the apparent absence of any real evidence of "split rings" (Graham, *et al.*, 1954; Trout, 1954, 1958) or spawning checks in addition to winter rings, and failing any other method of obtaining consistency of reading, each hyaline zone, which may be traced along the shorter axis when the cross section of the otolith is examined, has been regarded as representing a further year of life. Checks or false hyaline zones do occur and may often be seen in the otoliths of the small fish of the 1953 year-class. In following this year-class, it has been noted that it is only the true hyaline zones which may be traced along the short axis, and that false hyaline zones or checks, when traced round to the short axis, disappear or combine with the true hyaline zone. This can also be seen in the photographs of the otoliths of both *Sebastes marinus* and *Sebastes viviparus* shown by Rasmussen (1958).

Ages have been estimated from samples of otoliths obtained from Hermitage Bay during trips in 1953, 1957, 1958, and 1959. Although these samples were obtained in different months and years, it is convenient, because of the large variety in ages occurring and the necessity of separating the males and females, to combine the samples in order to provide even an approach to an adequate total sample. Age estimations have been made from the otoliths of a total of 903 fish. Of these 205 fish were of the 1953 year-class. As this year-class appears to have shown unusually fast growth, and its numbers are so great relative to the other fish, these fish have been excluded in deriving the mean growth curves shown in Figure 7. Thus these curves are based on age estimations from the otoliths of 366 males and 332 females.

When the growth curves shown in Figure 7 are compared to those obtained by other redfish workers (Fig. 8), one point is immediately noticeable, namely that the ages reached by the oldest fish are considerably greater than those of older fish as estimated by other workers.

Of the data which are available on the growth of redfish in the North-west Atlantic region, those of Perlmutter and Clarke (1949) are concerned with redfish only to 10 years of age.

Kelly and Wolf (1959) show the growth curves of redfish from the Gulf of Maine for the years 1951, 1952, and 1953. These curves, together with those of male and female redfish from the Gulf of St. Lawrence (Steele, 1957) and those for male and female redfish from Hermitage Bay, are shown in Figure 8. All these curves, most likely, refer to North American *mentella*-type redfish. (Kelly and Wolf, 1959, while recognizing the rather uncertain taxonomic position of the North American form of redfish, in their final table class the Gulf of Maine redfish as *Sebastes marinus marinus.* It is the author's opinion and that of Templeman (1959) that the Gulf of Maine redfish are similar to the common North American type, and should be considered as of the North American *mentella* type.)

Marty (1958) shows the age composition of redfish catches from three areas in the North-west Atlantic. He does not, however, indicate whether these age composition data refer to *marinus-*, *mentella-* or mixed-type redfish, nor are the sexes separated. An approximate growth curve has been calculated from the tables showing size and age composition of the catches obtained from ICNAF Subdivision 3L (the north-east slope of the Grand Bank), and this curve is also shown in Figure 8. It is likely that these data also refer to *mentella*-type redfish, as it was for this "type" and in this region that the trawlers from the U.S.S.R. were fishing during the period October–December 1956 (Marty, 1958).

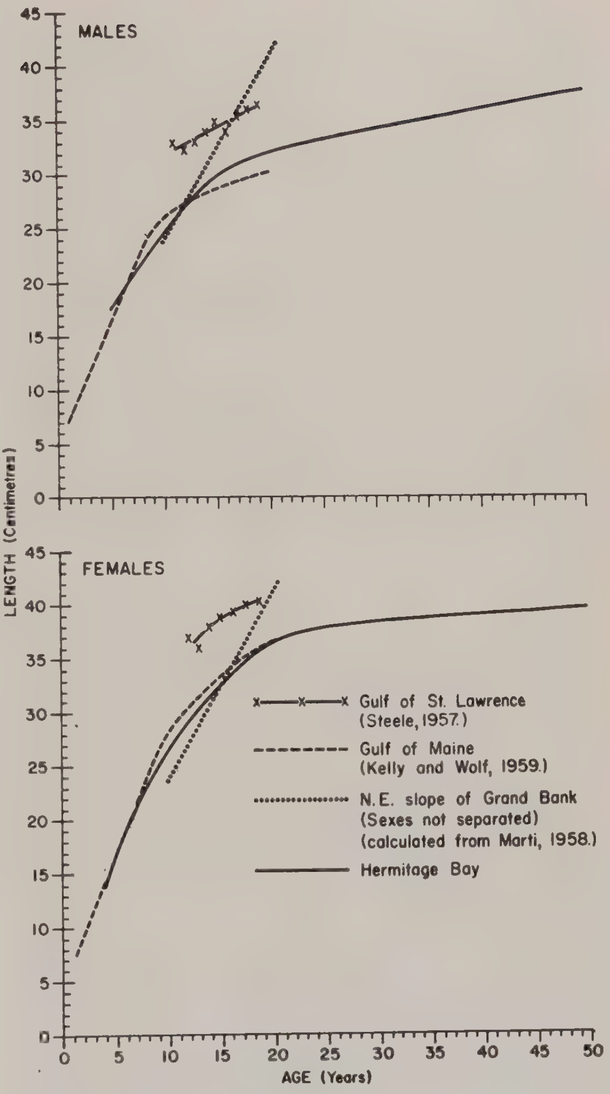

Figure 8. Growth curves of redfish from the North-west Atlantic.

Although the fish were from different areas of the North-west Atlantic, there is very close agreement in the age range 8–15, between the curves based on the age estimations of Kelly and Wolf, Marty and the present author. (It must be remembered that the curve derived from the data of Marty, 1958, refers to fish in which the sexes have not been separated.) After age

15, however, differences become apparent, and it would seem that the divergence between the curves is due to something more than differences in growth-rate between the areas concerned. This would most likely be due to a difference in method of age estimation.

Although not actually specified in his paper (Marty, 1958), subsequent conversations have indicated that most U.S.S.R. work on age determination of redfish is done by reading scales. If this is so, it seems likely that some of the difference between the approximate curve derived from Marty's data and the other curves shown in Figure 8, could be due to the use of scales rather than otoliths for age estimations.

Among those workers who have used otoliths for age estimation, a difference in method of age estimation could quite easily arise by the use of a different degree of magnification when examining the otoliths, and it is likely that the high ages obtained by the author for the larger fish in Hermitage Bay may be in part due to this. The hyaline zones, although distinguishable, are very fine, and in counting these zones, particularly near the edge of an otolith of an old fish, it was found necessary to use a higher magnification (30×) to remain consistent with regard to the principle that a single pair of zones constitutes an annual ring. It has been the writer's experience that if a high magnification is not used, many of the fine rings that occur in the otoliths of the very old redfish are not seen, and a low age estimation is obtained. It is noted in this respect, that Dr. Á. Friđriksson is cited by Parrish (1958) as having examined examples of *Sebastes* otoliths on which up to 70 winter zones could be counted.

The agreement between the growth curves for female redfish of the Gulf of Maine and Hermitage Bay is really remarkably close. It seems possible that the high sustained fishing pressure to which the Gulf of Maine has been subjected has resulted in the relative absence of the large very old fish.

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6.

Redfish, Growth and Age

By
E. I. SURKOVA
PINRO, Murmansk, U.S.S.R.

The increasing importance of redfish in northern fisheries during the recent years has intensified the studies of this highly interesting fish. Along with other biological problems, the study of the growth and age composition of the redfish stocks has acquired especial significance.

At present, two opinions can be defined concerning the growth and age of *Sebastes*. One is that these fishes have a rather high growth-rate, reach maturity at the age of 3–4 years, and live no more than ten years; also that the part of their stocks exploited by fishing consists of three to four age-groups.

The second opinion suggests very slow growth, maturity at the age of approximately 10 years, and life of 25–30 or more years. The redfish stocks exposed to fishing consist of at least 15 age-groups.

The problem of redfish growth and age is of great practical importance. If this fish has a short life cycle and is early maturing, the redfish stocks can be expected to be especially vulnerable to yearly fluctuations, and also, however, to be restored quickly from new, rich year-classes. Furthermore, in the case of a short life cycle, the need for the regulation of fisheries and for stock protection is not so pressing. If the second opinion is correct, it must be assumed that due to the many year-classes forming the fishable part of the population, the redfish stock may be more stable; however, if a strong increase of fishing intensity takes place, it may reach a state of long depression, which can be restored only with difficulty. It is natural that under the latter conditions it is necessary to employ the advance measures aimed at the regulation and rationalization of the fishery.

The first point of view, whose active adherent is Dr. A. Kotthaus, is more advantageous for the fishery. However, the majority of investigators, including the Soviet scientists, adhere to the second opinion on the growth-rate and age of redfish.

Table 1
Redfish, growth and age according to Kotthaus' data

Age	Length variations (cm)	Mean length (cm)	Annual growth (cm)
1 ………………	11–22	17·2	17·2
2 ………………	15–31	22·2	5·0
3 ………………	22–40	34·2	12·0
4 ………………	33–46	39·1	4·9
5 ………………	37–51	43·8	4·7
6 ………………	43–55	49·0	5·2
7 and older ……	45–81	–	–

The Symposium, after examining the data contributed by all participants, must either recognize the correctness of one or the other opinion and draw the proper conclusions as to the evaluation of the redfish stock and its prospective fishery, or, if the data are recognized as not convincing, the Symposium must prepare a programme and methods for subsequent joint investigations for an early solution of the problem.

Dr. Kotthaus, analysing the material collected in the course of the extremely active German redfish fishery, makes the supposition that not one but 3–4 rings are formed in the redfish scales and otoliths during each year, due to the sharp changes in the feeding of redfish during their migrations. To distinguish the annual rings, he suggested decreasing magnification, used for age determination, from 20–25 times to 5–7 times. He believes that in this way only the annual rings would be seen and all the supplementary rings would disappear as being less distinct. As a result of his studies, Dr. Kotthaus contends that at the end of the first year of life, redfish reach a length of 11–22 cm (mean length 17·2 cm) and that the largest redfish specimens are 7 years old or a little older (Table 1).

It is thought that such a great change in magnification during age determination is not justified from the methodical viewpoint. It is known that almost all fishes have annual rings, defined differently apparently in

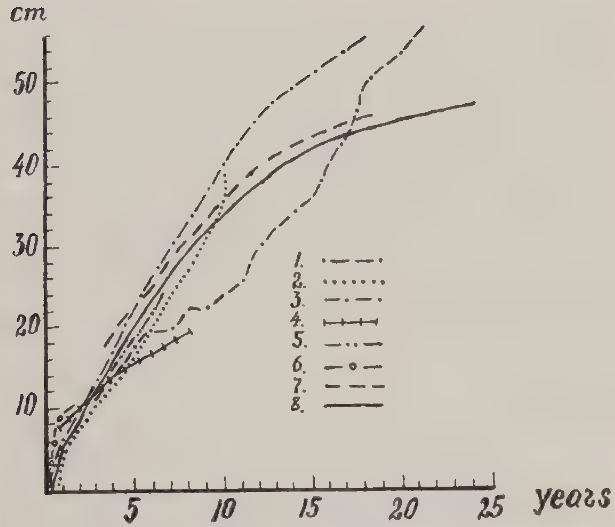

Figure 1. Redfish growth according to different authors' data.

1. Smaragdova, *S. marinus*
2. Veshchezerov, *S. marinus*
3. Travin, *S. marinus*
4. Bigelow & Schroeder, *S. marinus*
5. Bratberg, *S. marinus*
6. Sandeman, *S. marinus*
7. Travin, *S. mentella*
8. Surkova, *S. mentella*

connection with changes in life conditions. It is obvious that using Dr. Kotthaus' method, the growth of even such fish where the age composition of the stock does not require, at present, any major corrections, would be in doubt. It would be more convincing and more logical to use the universally recognized magnification which permits all the annual rings on the scales and otoliths to be seen, and to try to find criteria for differentiating the annual and supplementary rings. It is interesting to note that one redfish species, *S. viviparus,* which does not accomplish long migrations, has annual rings of a character similar to that of *S.marinus* and *S. mentella.*

It is impossible not to agree with Dr. Kotthaus that marking experiments and direct observation of redfish in an aquarium – that is, data which no one has been able to obtain as yet – would furnish the most objective and the most reliable proof of Dr. Kotthaus' or the opposite theory.

However, it seems that even without those data some material illustrating the redfish growth can be obtained convincingly enough. Redfish fry samples, present in most of the scientific research institutes working in the North Atlantic, may form part of such material.

Earlier investigations on the redfish growth, by means of back calculation, show that at the end of the first year of life redfish reach a length of 4–10 cm (with the mean size of 5–7 cm), with subsequently diminishing annual length increments. These data are very similar to the data collected by most scientists from other countries (Bigelow and Schroeder, Bratberg, Sandeman, and others) (Fig. 1), and differ essentially from Dr. Kotthaus' data. In the light of discussion, it was found necessary to verify the back calculation results by direct measurements of the redfish length at the first year of its life and at the same time to determine the periods of formation of the annual rings.

Samples of redfish fry of non-commercial sizes (from 4 to 30 cm) are available in collections from different areas of the Barents Sea (Fig. 2). These juveniles were captured by means of an ordinary trawl and also by a trawl equipped with a special small-meshed net inserted into the cod-end, with the mesh size of 10 mm between knots. 2,316 specimens were collected during 1957–1959. The analysis of the samples has shown that the smallest redfish (less than 10 cm) were caught more frequently in the winter–spring period, from January to May (Table 2). As the period of liberating larvae in the Barents Sea is April–May, it can be concluded that the fry of a size less than 10 cm belong to the year-class of the preceding year or earlier.

Table 2

Date and place of catches of redfish fry of less than 10 cm

Year	Month	Region	Minimum size of fry (cm)
1956	February	Kildin Bank	6
	"	Murman West coast	8
	March	Nordkyn Bank	4
	"	Demidov Bank	8
	September	Rybachi Peninsula Bank	8
1957	March	Demidov Bank	4
	"	Western Deep	4
	April	Nordkyn Bank	4
	"	Kildin Bank	8
	December	Andey Bank	8
1958	January	Demidov Bank	4
	"	N-E slope of the Murman Bank	6
	"	Central Gully	4
	"	Finnmarken Bank	4
	"	Central Plateau	6
	August	Rybachi Peninsula Bank	8
	December	W slope of the Goose Bank	8

Observations on the scales of these young fish confirm the conclusion that the majority of them have one annual ring formed and often show a considerable increment thereafter (Figs. 3–7).

The data collected seem indisputable, and, based on the annual ring formation and on the size of the redfish by the end of its first year, an age analysis of the available fry samples has been made. It is found that redfish, having lengths from 4 to 30 cm, are 1 to 10 years

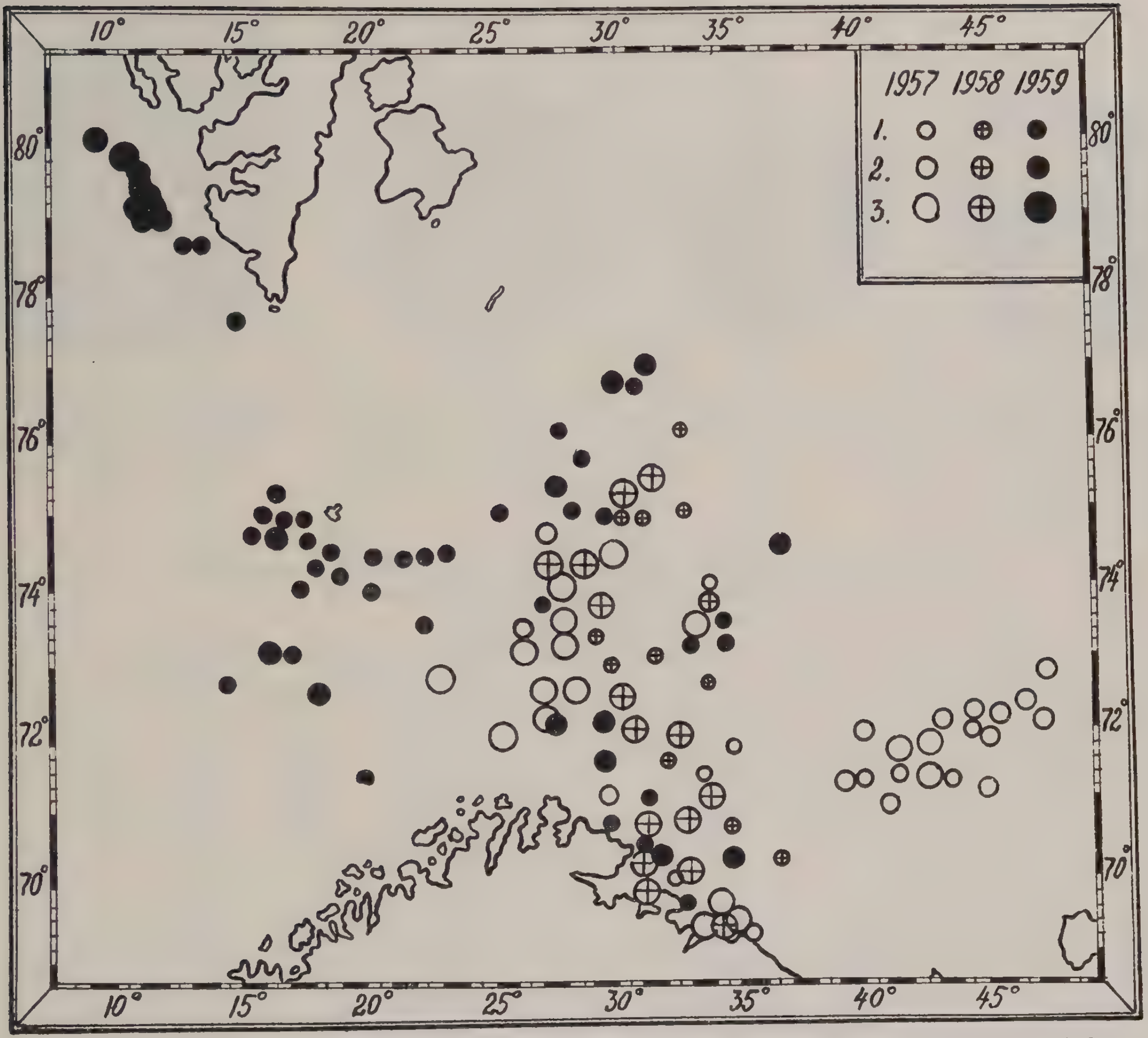
10°
15°
20°
25°
30°
35°
40°
45°
80°
78°
76°
74°
72°
70°
1957 1958 1959
1. ○ ⊕ ●
2. ○ ⊕ ●
3. ○ ⊕ ●

Figure 2. Positions where redfish fry were captured. 1. = 1–20 ind.; 2. = 20–100 ind.; 3. = over 100 ind.

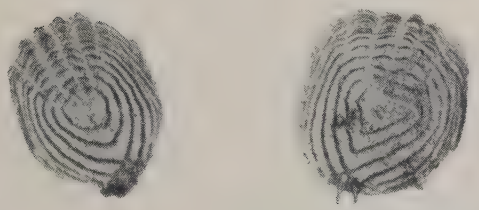

Figure 3. Scales of redfish, 5·7 cm long, one year old, Nordkyn Bank, 5. April 1957, "Persey 2", trip 96, tr. 43.

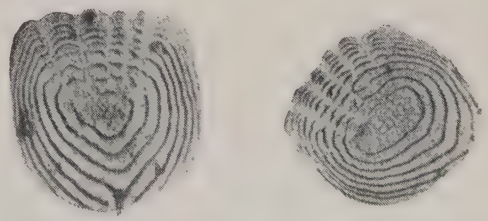

Figure 4. Scales of redfish, 6·7 cm long, one year old, Nordkyn Bank, 27. March 1957, "Persey 2", trip 96, tr. 30.

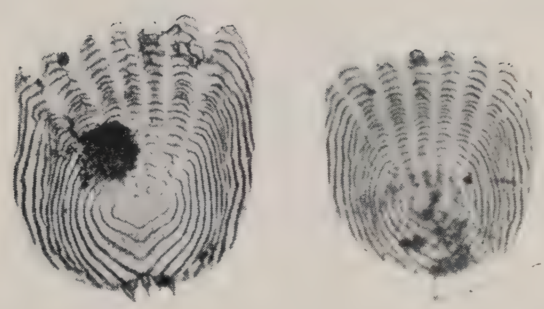

Figure 5. Scale of redfish, 8·0 cm long, age 1+, second annual ring not yet formed. West Gully, 14. January 1959, RT-211, trip 5, tr. 33.

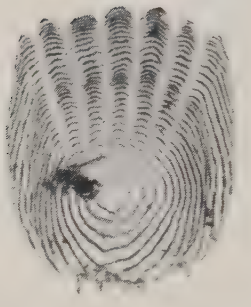

Figure 6. Scale of redfish, 9·8 cm long, two years old, West Spitsbergen, 3. June 1959, RT-191, trip 6, tr. 23.

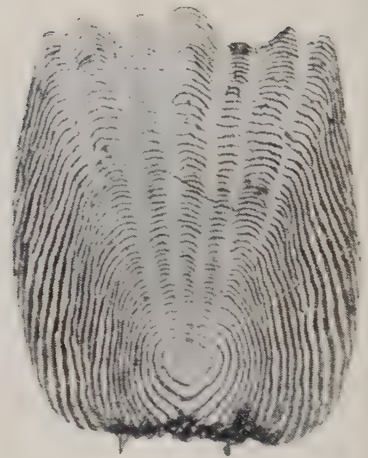

Figure 7. Scale of redfish, 13·1 cm long, 3 years old, West Spitsbergen, 3. June 1959, RT-191, trip 6, tr. 23.

Table 3

Size and age composition of the most typical samples of young redfish in the Barents Sea during 1957—1959

Areas	Months	Length variations (cm)	Mean size (cm)	Age	Number of Specimens
1957					
Central areas	January	14–24	16·46	2–8	46
	November	14–25	19.10	3–8	42
	December	15–19	16·75	2–7	30
Western areas	March	6–15	8·53	1–5	206
	April	6–15	7·50	1–4	74
	July	8–21	12·84	2–7	31
Coastal areas	April	9–13	11·44	2–7	18
1958					
Western areas	January	10–30	21·18	2–10	321
	February	7–28	9·71	1–10	44
	August	10–26	16·52	2–8	55
	September	14–26	20·89	3–8	20
Coastal areas	November	14–29	20·76	4–9	48
1959					
Western areas	May	5–19	11·49	1–6	157
Coastal areas	April	6–22	15·83	1–7	46
North-Western areas	January	8–32	23·49	2–11	54
	March	6–17	11·58	1–8	36
	June	6–16	10·03	1–5	433

old (Table 3). Yearlings that occurred in samples (with one very distinct annual ring) had a length of 4 to 10 cm, with the mean length of 6·3 to 8·3 cm, i.e. a half or a third as small as they would be according to Kotthaus. An overestimate of the mean sizes of the yearlings observed by direct measurements (in comparison with the back-calculated sizes) may, in the author's opinion, be explained by the Lee phenomenon or by a partial escapement of the small specimens through the trawl, even though equipped with a small-meshed net.

A back calculation of the growth-rate of *S. mentella* Travin caught on the Kopytov ground in 1958 was also made (Table 4). The results confirmed the previous observations. No considerable change in growth-rate of *S. mentella* Travin from the Kopytov area has been observed during 1953–1958.

Thus, it is believed that there is no reason to change the opinions on redfish growth stated earlier and these do not agree with Dr. Kotthaus' point of view.

During the years of Soviet fisheries in the Kopytov area (from 1953), the age composition of the *S. men-*

Table 4

S. mentella growth-rate on Kopytov Bank in 1958 (calculated)

Age	Males			Females			Total		
	Number of specimens	Mean length (cm)	Growth-rate (cm)	Number of specimens	Mean length (cm)	Growth-rate (cm)	Number of specimens	Mean length (cm)	Growth-rate (cm)
1	204	4·87	4·87	194	5·11	5·11	398	4·99	4.99
2	204	8·43	3·56	194	8·69	3·58	398	8·55	3·56
3	204	12·15	3·72	194	12·21	3·52	398	12·25	3·70
4	204	15·41	3·26	194	15·41	3·20	398	15·41	3·16
5	204	18·47	3·06	194	17·43	2·02	398	18·33	2·92
6	204	21·23	2·76	194	21·15	3·72	398	21·23	2·90
7	204	23·83	2·60	193	23·31	2·16	397	23·67	2·44
8	198	25·97	2·14	187	25·71	2·40	385	25·87	2·20
9	190	28·09	2·12	179	27·79	2·08	369	28·03	2·16
10	185	30·21	2·12	173	29·73	1·94	358	29·89	1·86
11	177	31·89	1·68	173	31·73	2·00	350	31·81	1·92
12	175	33·37	1·48	159	33·23	1·50	334	33·35	1·54
13	163	34·33	0·96	154	34·93	1·70	317	34·91	1·56
14	147	36·03	1·70	133	35·97	1·04	280	36·07	1·16
15	124	36·99	0·96	116	37·31	1·34	240	37·13	1·06
16	100	37·85	0·86	94	38·25	0·94	194	38·15	1·02
17	65	38·39	0·54	73	39·11	0·86	138	38·77	0·62
18	40	39·44	1·05	55	40·11	1·00	95	39·64	0·87
19	16	39·05	0·00	32	40·93	0·82	48	40·31	0·67
20	9	39·72	0·67	20	41·52	0·59	29	40·99	0·68

Table 5

S. mentella percentage age composition in the Kopytov region during 1953—1958

Fishery years	Age										Number of specimens	Mean age
	<13	13	14	15	16	17	18	19	20	>20		
1953	5·3	4·0	9·0	15·3	15·9	18·2	15·9	9·7	3·8	2·9	1361	16·5
1954	13·1	5·7	6·3	14·5	17·0	17·5	13·9	7·5	3·5	1·0	1126	15·8
1955	6·1	9·6	11·8	19·7	17·9	16·2	12·3	4·8	1·3	0·3	1632	15·7
1956	11·8	7·9	10·6	14·2	15·8	15·0	13·6	5·1	4·1	1·9	1357	15·6
1957	20·2	10·0	12·2	15·6	15·4	13·6	8·5	2·8	1·1	0·6	1179	15·0
1958	12·8	8·2	13·0	14·8	15·2	13·0	10·5	5·8	3·3	3·4	1103	15·6

tella Travin stock has undergone some changes due to the decrease of the mean age (Table 5). This may serve as an additional proof of the view of redfish growth and rate of reproduction. The intensive fishing for redfish during the 6-year period, with insufficient recruitment, has resulted in a certain decrease in the number of fish of older year-classes.

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7.

The Growth of Immature *Sebastes viviparus* (Krøyer) from the North Norwegian Coast

By

G. C. TROUT
Fisheries Laboratory, Lowestoft

Tåning (1943) showed that *S. viviparus,* the "lille rødfisk", was taken in the commercial catches at Faroe. Elsewhere in Europe this species does not make any noticeable contribution as a food fish, being on the whole too small or perhaps because it is not differentiated from other redfish. There has been little incentive, therefore, to examine its growth-rate and only Rasmussen (1958) has given even a rough approximation to its annual increment of growth.

As the otolith of *S. viviparus* from the Norwegian coast appeared to be extremely easy to read, a small and restricted material, comprising some 560 otoliths, together with length data, was worked through in the hope that it might shed some light on redfish otolith structures and their interpretation.

The material was derived from six single hauls on the Malangen Bank on the north coast of Norway, during periods in 1957 and 1958 when the "Ernest Holt" was in the area to work the Malangen Hydrographic Section. A haul for redfish was made when and where convenient, merely as an incidental part of the cruise.

Ekström (1836) considered 20 to 60 fathoms to be the distribution in depth of this species. Collett (1885), however, gave a deeper range, down to 150 or even 200 fathoms. The present material was derived from the deeper part of the species range (see foot of Table 1 for depth range of samples) and from temperatures of approximately 7·7°C (M.A.F.F., 1957 and 1958). It was limited to cover catches, obtained from a nylon shrimp-mesh cover attached to the 110 mm cod-end of the "Ernest Holt's" standard trawl. Periods of sampling were restricted to the winter months, (February, March, and November) so that all specimens had either completed the bulk of their current year's growth, or were about to begin it.

The cover catches contained the young of both *S. marinus* and *S. viviparus* and some difficulty was experienced at first in separating them. Mistakes were made in identification at sea, until Andriiashev's key (1954) became available. After a time the robust and chunky outline of *S. viviparus* became more readily distinguishable without fin-ray counts. Andriiashev's key proved invaluable and in particular the separation of the species by the pre-opercular spines was found to be most reliable. In heavy catches, however, damage caused to the backward-pointing spines made it necessary to examine both sides of the head in order to determine whether an apparent *S. marinus* was, in fact, a *S. viviparus* with its pre-opercular spines removed by the crush in the cod-end. Because of this, the last five samples were brought back to the laboratory in alcohol (70 %) for identification, measurement (in mm to the nearest mm) and otolithing.

On the whole, most of the *S. viviparus* specimens collected were small and immature. Table 1 gives the size and age composition of the six samples, totalling 547 observations. It will be seen that two year-classes predominate, those of 1953 and 1949, with 4 and 8 complete opaque zones in 1957 and with 5 and 9 respectively in 1958. The range in size of fish of a given zone count is considerable and noteworthy. Sexes were not separated and are probably responsible for some of the spread of the observations.

Table 1
Length and age distribution of *S. viviparus*, from six samples taken from hauls made on the Malangen Bank

Length (mm)	Age (years)													
	3	4	5	6	7	8	9	10	11	12	13	14	15	16
75–79	–	2	–	–	–	–	–	–	–	–	–	–	–	–
80–84	1	5	2	–	–	–	–	–	–	–	–	–	–	–
85–89	–	11	4	–	–	–	–	–	–	–	–	–	–	–
90–94	–	14	16	–	–	–	–	–	–	–	–	–	–	–
95–99	–	10	27	–	–	1	–	–		–	–	–	–	–
100–104	–	5	22	–	–	–	–	–	–	–	–	–	–	–
105–109	1	9	36	1	–	–	–	–	–	–		–	–	–
110–114	–	2	27	1	–	1	6	–			–	–	–	–
115–119	–	2	22	–	–	5	2	–	–	–	–	–	–	–
120–124	–	–	13	–	–	8	9	–	–	–	–	–	–	–
125–129	–	1	6	–	–	11	9	–	–			–	–	–
130–134	–	–	2	–	–	7	18	–	–	–	–	–	–	–
135–139	–	–	–	–	1	6	23	–	–	–	–	–	–	–
140–144	–	–	–	–	–	7	22	–	–	–	–	–	–	–
145–149	–	1	–	–	–	8	20	–	–	–	–	–	–	–
150–154	–	1	–	–	1	4	23	–	–	–	–	–	–	–
155–159	–	–	–	–	–	5	18	1	–	–	–	–	–	
160–164	–	–	–	–	–	4	8	–	–	–	–	–	–	–
165–169	–	–	–	–	–	3	10	–	–	–	1	–	–	–
170–174	–	–	1	–	–	1	8	–	–	–	–	–	–	–
175–179	–	–	–	–	–	3	6	–	–	1	–	1	–	–
180–184	–	–	–	–	–	1	3	–	1	–	–	–	1	1
185–189	–	–	–	–	–	1	3	–	–	–	1	1	–	–
190–194	–	–	–	–	–	–	1	1	–	1	–	–	–	–
195–199	–	–	–	–	–	–	1	–	–	–	–	–	1	–
200–204	–	–	–	–	–	–	–	–	–	–	1	–	–	–
205–209	–	–	–	–	–	–	–	–	1	2	–	–	–	–
210–214	–	–	–	–	–	–	–	1	–	2	1	–	–	–
215–219	–	–	–	–	–	–	–	–	–	1	2	–	–	1
220–224	–	–	–	–	–	–	1	–	–	–	–	–	2	–
225–229	–	–	–	–	–	–	–	–	–	1	1	–	2	–
230–234	–	–	–		–	–	–	–	–	–	–			
235–239	–	–	–	–	–	–	–	–	1	–	–	–	1	–
240–244	–	–	–	–	–	–	–	–	–	–	–	–	–	–
245–249	–	–	–	–	–	–	–	–	–	–	–	–	–	–
250–254	–	–	–	–	–	–	–	–	–	–	1	–	–	–
255–259	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Total	2	63	178	2	2	76	191	3	3	8	8	2	7	2

			N	E		
Sample 1.	ST. 11	1/57	69°45′	16°53′	260/140 fm	7.3.57
	ST. 86	1/57	70°21′	17°20′	150/90 fm	18.3.57
„ 2.	ST. 34	1/58	70°30′	18°02′	95 fm	9.2.58
„ 3.	ST. 12	VI/57	70°07′	17°15′	80 fm	25.11.57
„ 4.	ST. 27	II/58	70°30′	17°40′	150/170 fm	16.3.58
„ 5.	ST. 27	II/58	70°30′	17°40′	150/170 fm	16.3.58
„ 6.	ST. 12	VI/57	70°07′	17°15′	80 fm	25.11.57

Age determination

This was found relatively easy and was carried out by means of the otoliths. These were viewed whole, flat, in water or alcohol, rarely xylol, and were illuminated by reflected light against a black background. A low-powered binocular microscope (approx. × 15) was used. About 97 % of the samples were read without trouble. Of the remainder some were from mature fish – over the age of about 12 years – and the post-maturity rings could not be read with certainty, though it was found that by cutting these mature otoliths, the multitudinous indistinct and thin opaque rings tended to be groupable. Too few matures were present in these cover samples for any conslusions to be drawn. Other, younger, otoliths were doubtful merely owing to their dense structure or to coalescing or diffuse adjacent opaque zones.

It can be said that a feature of the *S. viviparus* otolith, when viewed whole, was the clear separation into relatively wide, single opaque zones and narrow hyaline zones. One fact, outlined by Rasmussen (1958) was

Table 2. Length at age

Age (years)	4	5	8	9	12	13
Mean length (mm)	97·9	107·7	141·3	148·0	206·9	210·6
Variance (σ^2)	194·6	132·0	344·7	328·5	238·9	656·7
Standard deviation (σ)	±13·95	11·49	18·57	18·12	15·46	25·63

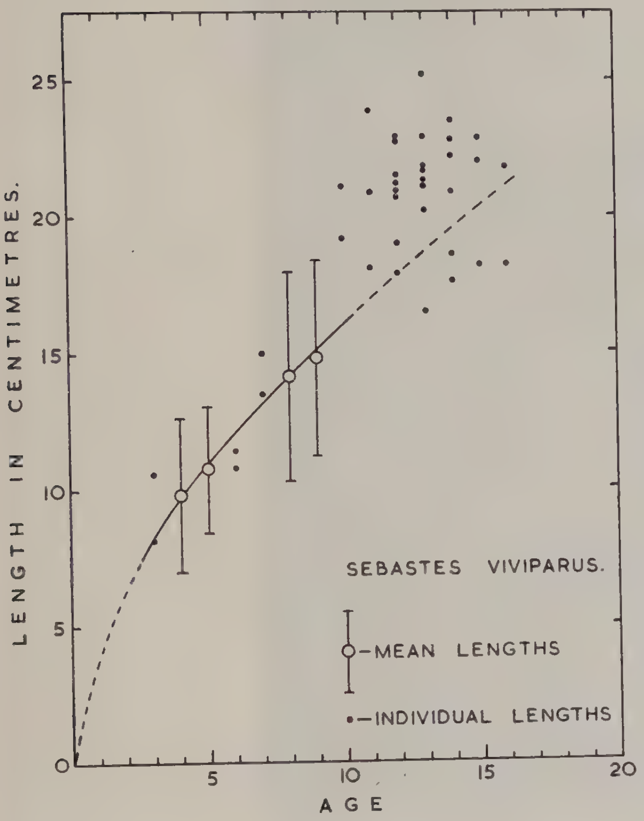

Figure 1.

confirmed, namely that the otoliths of this species differ radically in appearance from those of other redfish forms found in the Barents Sea. This was indeed fortunate, for it permitted wrong identification at sea to be rectified since it was quite simple to separate the otoliths from a mixed sample. This was simpler and the differences were more apparent when the otoliths were viewed whole, rather than when cut as suggested by Rasmussen.

Otolith structure was clearest and samples were most easily read when they were (a) examined immediately after removal from the fish, (b) when stored wet, either in sea water, fresh water, or alcohol (70 %). If stored dry, then immersion in alcohol or sea water for between 30 minutes and 24 hours, according to size, would return them to a readable condition. Xylol tended to "clear" otoliths too drastically and some of the opaque material was lost, especially in small otoliths, after even short immersion.

Although the seasons of sampling were limited, there was sufficient spread to say that opaque zone formation began after March and was complete by November, approximately. It has not been possible to arrange year-round sampling to delimit the timing of zone completion more precisely.

The crude growth curve derived from this material is given in Figure 1 and is offered with some reservations, although the four points obtained from the 4, 5, 8, and 9 year-olds may be considered reasonably reliable. They were derived from 508 of the 547 observations. The recurrence of the two predominant year-classes in the second year of sampling is taken as evidence of only one opaque zone being laid down each year.

Table 2 shows the standard deviation, and twice this value is plotted for these four points on the curve – it is thought that the observed lengths of the older fish are probably biased and too high. These were probably influenced by the very small number of 12 and 13 year-olds, of which only eight of each were contained in the total sample.

It will be seen that the growth of *S. viviparus* is very slow compared with that of *S. marinus* and *S. mentella* of the Barents Sea (Travin, 1951), but approaches that of redfish of the Gulf of Maine, described by Perlmutter and Clarke (1949) and with which it appears to have a closer affinity than with *S. marinus* (Trout, this volume, pp. 94–99).

Three phenomena, observed generally throughout this material, are of interest.

(i) Despite the small level of the sampling in the two years, the unequal representation of the age-groups was consistent and very apparent. The intermediate year-classes between those of 1949 and 1953, and both older and younger year-classes, were virtually absent. Ignoring the selection, by the 110 mm cod-end and shrimp netting of 9 mm bar mesh of the upper and lower ends of the length range, it is evident that recruitment to the one deep area sampled is intermittent. Whether this also reflects the true recruitment to the Norwegian coast stock cannot be said, but material from the Faroe Island population of *S. viviparus* indicates that similar intermittent recruitment also occurs there.

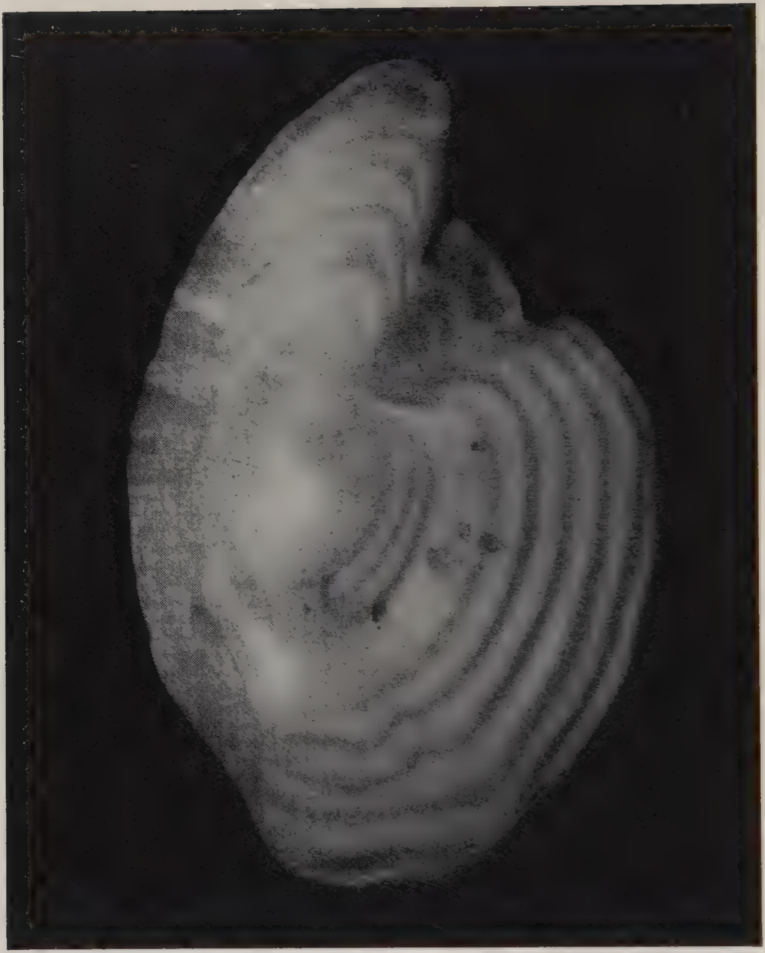

Plate 1. Otolith of *Sebastes viviparus* showing sequence of wide and narrow opaque zones.

(ii) Plate 1 illustrates the difference in width of groups of four opaque zones observed in these samples – a constant feature in this material. This grouping and the intermittent recruitment originally led the writer to think that four opaque zones per year were produced.

(iii) Normally the hyaline zones of these otoliths were relatively narrow, but those of a particular winter – that of 1956/1957 – were of considerable width and showed in each of the samples, irrespective of age – Plate 2. No explanation is proffered at this stage, but these features frequently proved to be useful in checking the age of a difficult otolith.

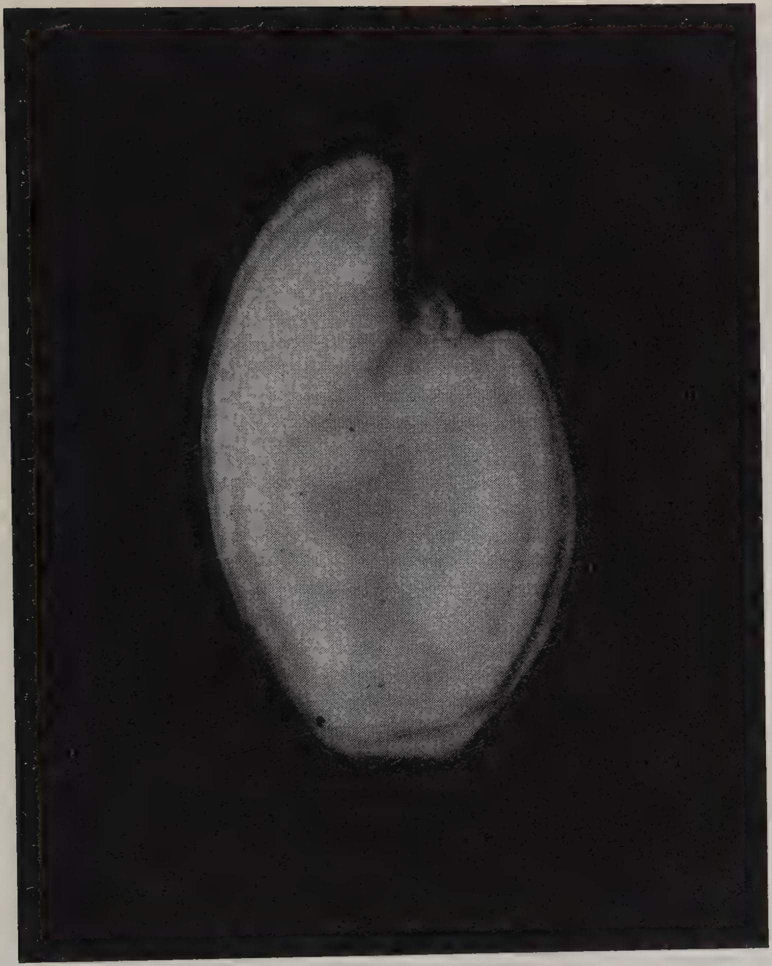

Plate 2. Otolith of *Sebastes viviparus* showing wide hyaline zone of the 1956/57 winter.

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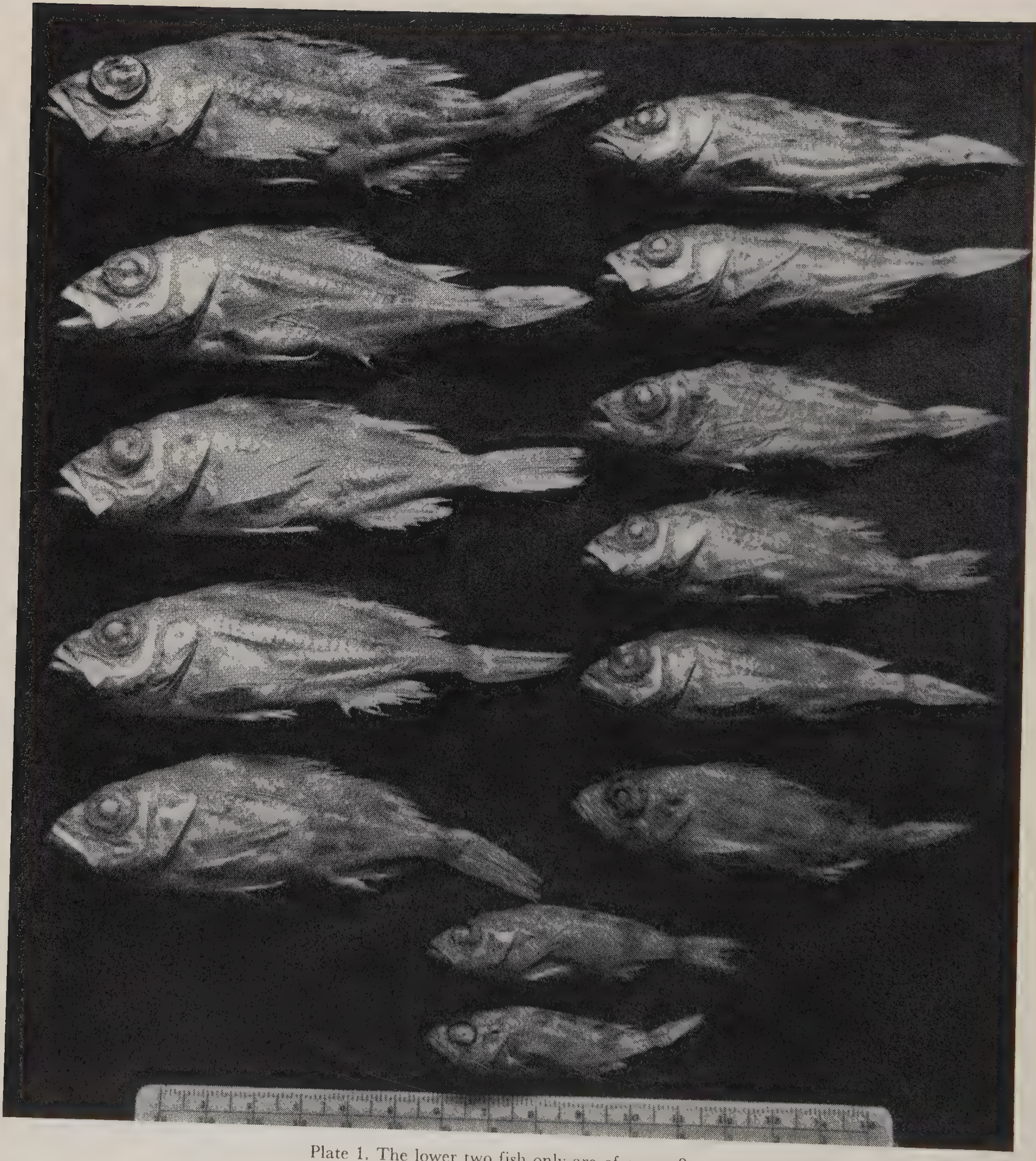

Plate 1. The lower two fish only are of group-0.

8.

The Otolith of Group-0 *Sebastes mentella* Travin

By

G. C. TROUT
Fisheries Laboratory, Lowestoft

One of the most controversial redfish problems has been the interpretation of the opaque structure of their otoliths, when used for age determination. This has resulted in alternative estimates of growth-rates being put forward. Examination of a sample of bottom living young *Sebastes* has been of interest, since it throws some light on this problem. (Two specimens of this sample of 40 are shown, Plate 1, with other larger fish, of the same species, from the same haul.)

The sample was caught by the R/V "Ernest Holt", west of Bear Island in 182 metres (position 74°28′N, 17°02′E) on 30. November 1957, by means of a shrimp netting cod-end cover of 9 mm bar mesh on the normal trawl. The young fish ranged from 53 to 67 mm in length and were thought to belong to the brood of the year. Assuming larval release to be in May/June, these fish were appoximately six months old and this assumption was supported by the earlier work of Jensen (1922), and Travin (1951) (and also by Surkova and by Einarsson in their papers submitted to the Symposium).

Although these fish were so small, their general appearance, eye size, and the presence of a "chin", the point of which could be seen and felt to differ from other *Sebastes* juveniles, indicated that these were, most probably, the young of *S. mentella,* which is readily separable from *S. marinus* in the larger, commercial, size ranges.

The first obvious point of interest, on examining the otoliths, was their variable shape and appearance, which argued that these fish were very young and had not achieved the characteristic overall shape of the adult (Plate 2). Despite this, there were, however, three clearly recognizable and separate opaque zones:–

(i) a densely opaque, large, central nucleus, separated by a very narrow hyaline zone from
(ii) a narrow opaque zone, usually slightly less dense than the nucleus;
(iii) the outermost opaque zone, wider but less dense than the previous zone.

The two hyaline zones separating the three opaque zones were only between 2 and 6 eyepiece units in width. A wide hyaline zone was at the edge of the otolith and was approximately the same width as the adjacent opaque zones.

Measurement of the successive structures, across the equator of each otolith, gave the following mean values, in e.p.u.s. (for righthand otoliths, outer surface):–

Hyaline edge	Opaque$_1$	Opaque$_2$	Nucleus	Opaque$_2$	Opaque$_1$	Hyaline edge
19·8	18·1	14·0	231·4	23·7	23·0	24·0

Since the age of these fish, of mean length 61 mm, is unlikely to be more than six months, it must be assumed that, in the Barents Sea at least, the nucleus is a composite structure. It is thus liable to give rise to differences and inconsistencies in age determination of larger, commercial sized redfish, unless adequate safeguards are taken against arbitrary grouping of zones.

The mean total width of these group-0 otoliths was 354 eyepiece units. This approached, very closely, the size of the composite structure assumed to be the first year's growth in otoliths from fish of commercial sizes. The approximate mean otolith widths derived from the first five years of 20 *Sebastes mentella,* ranging in length from 24 to 42 cm were as follows, measurements being made on the cut face of the otolith's equator:–

Total width				
Year 1	Year 2	Year 3	Year 4	Year 5
358	546	659	774	871

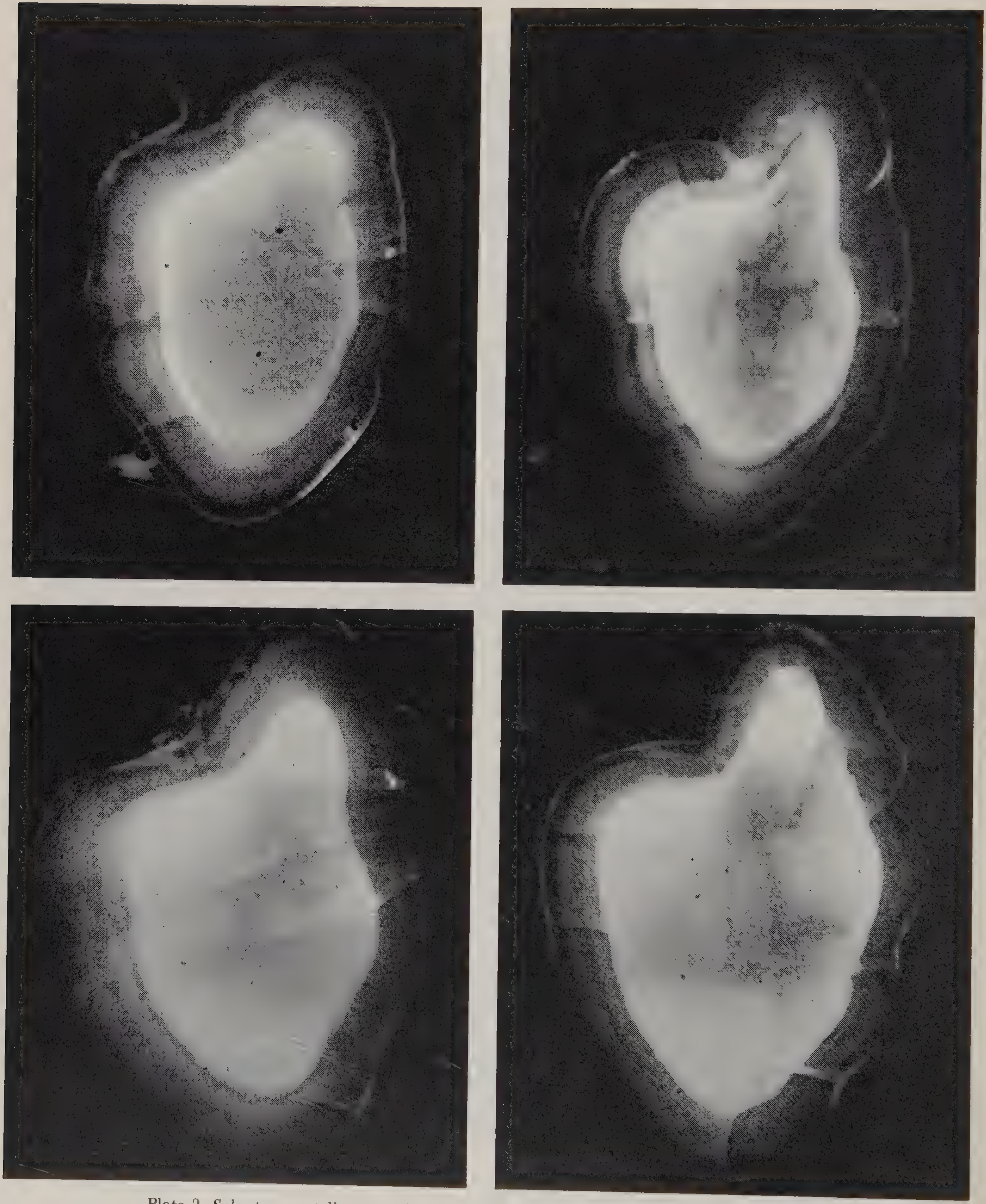

Plate 2. *Sebastes mentella* group 0 otoliths from fish of length 56, 61, 65, and 67 mm.

Measurements of later year growth zones were found to be more variable and difficult to make, whilst the spread of values obtained from the small sample, increased. The mean lengths of the fish, at the ages determined with the aid of these measurements, agreed reasonably well with those of Travin's growth curve (1951) and with the data of Surkova (this volume), which were based on scale readings.

Whilst the material described was small and limited, it demonstrated the composite structure of the nucleus in the Barents Sea *S. mentella*. Observations from otoliths of larger, commercial sized fish of the same species, show that this composite structure is visible in the cut otolith.

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SECTION VI

A BIBLIOGRAPHY OF THE NORTH ATLANTIC REDFISH

By

G. C. TROUT
Fisheries Laboratory, Lowestoft

At this early stage in the study of the Redfish and whilst the systematics of the genus are still unresolved, no attempt has been made, in compiling this bibliography, to classify the literature by species.

The bibliography consists, therefore, of a simple subject index for each of six broad headings. Two of these, namely Biology and Population Studies, are subdivided further. No annotation has been attempted, again, largely because of the uncertainty of species.

The bibliography is not exhaustive but it is thought that all major works, both modern and of historical interest and value have been included. Some details of a few of the earlier works are still in doubt and such references are so marked.

Some works have been excluded deliberately:–

(i) Check lists, (ii) Records of isolated or rare occurrences of redfish, either in commercial catches or during exploratory voyages, (iii) Annual Reports which are mimeographed rather than published. These are usually concerned with unfinished researches, tend to be given a restricted distribution, and are frequently anonymous, (iv) Documents presented at international meetings (except a number of those presented at ICES meetings). These are often in an interim report form and may well be modified before finally reaching their published form, (v) Reports which are in effect administrative reports of work being carried out on redfish but which contain no data or results.

The Bibliography has been amended to include individual references contained in the Annual Proceedings of I.C.N.A.F., in compliance with the wishes of the Symposium.

It is hoped that each work appears in all subject indexes which its contents justify. Some papers, particularly those for which no full translations are available, may be incompletely indexed.

Acknowledgements

I would like to record my thanks to Miss Eileen Howard, Librarian at the Fisheries Laboratory, Lowestoft, and to her staff, on whom fell the main burden of checking each reference which appears in the Bibliography.

My thanks are also due to Mr. Leon Birkett for frequent help with the translation of Russian papers and references.

Subject Index

- I. Statistics
- II. Systematics
- III. Biology
  - (i) General and popular
  - (ii) Distribution
  - (iii) Reproduction
  - (iv) Larvae and larval distribution
  - (v) Food and feeding
  - (vi) Parasites, predators, and disease
  - (vii) Physiology and biochemistry
- IV. Population Studies
  - (i) Ichthyometrics
  - (ii) Age determination and growth
  - (iii) Selectivity
  - (iv) Effects of fishing
- V. Technology and Commercial
- VI. Special Publications for other regions concerning allied genera and species.

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